Small-sided games in youth soccer

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“Zaterdag is de mooiste dag van de week

En je wist als je naar je vriendjes keek

Hier staat het nieuwe oranje”

All Stars

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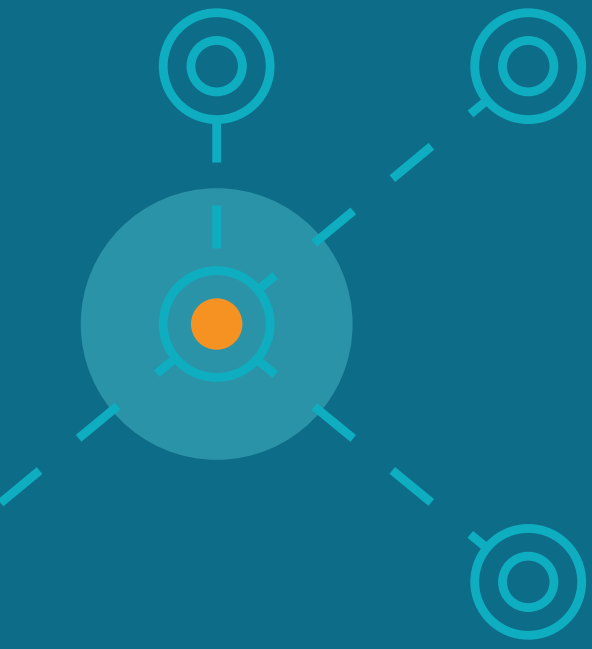

CHAPTER 1

General introduction

There is this game - played all over the world - called soccer. We play soccer in matches and we learn, improve, and refine soccer in training. Official regulations and playing rules define a match. In match-play, it is about performing and winning. The training is designed to emphasize and mimic specific situations of the match. In training, the focus is on learning. This thesis will focus on the relation between the match and training: can we replicate match behavior in training?

Football is a simple game: twenty-two men chase a ball for 90 minutes [...].

Gary Lineker - 1990

Official soccer match

Twenty-two players, representing two opposing teams, play soccer on a 105 x 68 m pitch with a ball, regulated by playing rules. This combination is specific for soccer and shapes the behavior of players during an official match (Glazier & Robins, 2013; Newell, 1986). A logical purpose of soccer is to win the match by scoring more goals than the opponent does. Players employ a combination of their physical, technical, and tactical capacities to reach this goal (Jones & Drust, 2007). However, there is a conflict in the relation between players present on the pitch: ball possession entitles players to attack and score a goal, but opponent players will make every effort to prevent that. This creates cooperation of players within a team and competition between players of opponent teams (Grehaigne, Bouthier, & David, 1997; McGarry, Anderson, Wallace, Hughes, & Franks, 2002). Moreover, teams try to score on different sides of the pitch. This oppositional relationship produces goal-directed behavior that goes back and forth in a predominantly goal-to-goal direction of the pitch (Frencken, Lemmink, Delleman, & Visscher, 2011; Grehaigne et al., 1997; McGarry et al., 2002).

A main objective in soccer science is to capture this goal-directed behavior. In performance analysis, researchers quantify a player's physical load, technical skills, and tactical decision-making in order to observe a player's activities in the real context of the match, instead of using field tests or laboratory experiments. Time-motion analysis is used to quantify physical load and movement activity patterns, like the distance covered, high intensity activities, and sprints. With video analysis, both technical and tactical skills can be observed. Technical skills are mostly determined by quantifying (successful or direction of) actions on the ball (Hughes & Bartlett, 2002; Vilar, Araújo, Davids, & Button, 2012), where tactical skills are mostly related to qualitative observations of decision-making (van Maarseveen, Oudejans, & Savelsbergh, 2017). At this point it is important to note that soccer players are considered as the performers

of the game (Glazier & Robins, 2013). In order to use consistent terminology throughout the thesis, a player's individual contribution to the game (in the physical, technical and tactical domain) will be called 'performance'. This is a commonly used term in soccer science literature, along with other terms like capacity, skill, demand, performance outcome, outcome of behavior, etc.

Thus far, performance analysis literature mainly gave insight into a player's individual soccer performance. However, soccer is by definition a team sport with an intermittent character where teams alternately attack and defend. Moreover, it is characterized by its (temporary) interactions between players, formation of sub-groups, and unpredictability. Rather than a limited focus on only individual performance, soccer science can benefit from a more comprehensive understanding of soccer performance, including analysis on a team level (Vilar et al., 2012). An ecological approach, such as the dynamical system theory, enables capturing and identifying collective behavior (Grehaigne et al., 1997; Seifert, Araújo, Komar, & Davids, 2017). A player's interaction with team members, opponents, and the environment define collective behavior (Grehaigne et al., 1997; McGarry et al., 2002; Seifert et al., 2017; Vilar et al., 2012). Such an ecological approach enables researchers to model and understand how players choose position and how teams organize and coordinate with respect to their opponent. In soccer science literature, collective behavior is also described as team tactical behavior. In this soccer context is team tactical behavior defined as the individual and collective actions of a team to best employ player skills in order to contribute to the team's goal of attacking and defending by goal scoring or preventing goals (Carling, Williams, & Reilly, 2005).

Collective behavior can be described as the dynamic relation at individual and team level, displayed as player-player (or dyadic), intra-team, and inter-team coordination. Dyadic coordination reflects the player's interaction with a team member or opponent player and is often displayed as the distance between two players (Bourbousson, Sève, & McGarry, 2010a; Gonçalves et al., 2017; McGarry et al., 2002; Vilar et al., 2014). Intra-team and inter-team coordination reflect the cooperation within a team or competition between teams, respectively. Corresponding measures focus on a team's centroid, dispersion of players, and synchrony of teams (Araújo, Silva, & Davids, 2015). Intra-team measures reflect the dispersion of players on the pitch and are displayed by variables such as length, width, length-per-width ratio, stretch indices, and surface areas (Bourbousson, Sève, & McGarry, 2010b; Folgado, Lemmink, Frencken, & Sampaio, 2014; Frencken et al., 2011). Inter-team coordination is often described by the distance between the team centroids: the team's central or geometrical gravity point (Frencken, Van Der Plaats, Visscher, & Lemmink, 2013). These variables, also referred to as team tactical (performance) measures, can be displayed as average values which

dominantly focus on the spatial dimension (figure 1.1). Temporal analyses on these variables identify tactical variability (Gregson, Drust, Atkinson, & Di Salvo, 2010) and interaction (Corbetta & Thelen, 1996), temporal synchronization (McGarry, 1999; Palut & Zanone, 2005), and regularity of synchronization (Duarte et al., 2013; Sampaio & Maçãs, 2012) between teams.

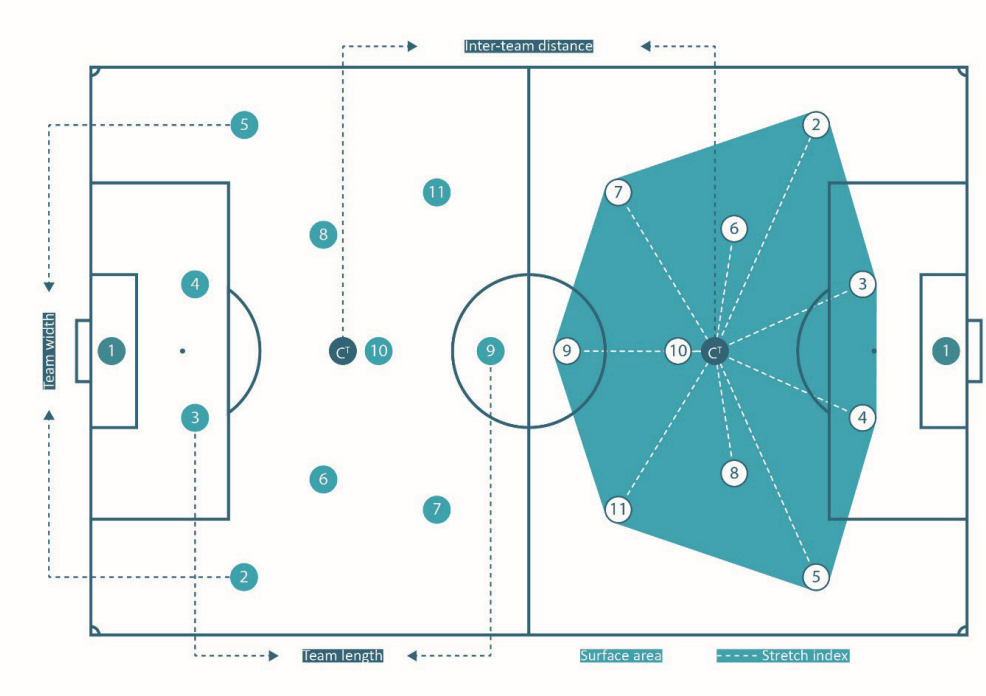

Figure 1.1. Formation of two teams with corresponding variables for intra-team and inter-team coordination. C^T: team centroid; length-per-width ratio is calculated as the team length divided by the team width; stretch index is the average distance of the outfield players to their team centroid.

Small-sided games

In order to improve individual performance and collective behavior, small-sided games are a widely used training format. Small-sided games are derived from the match with manipulations in number of players, pitch size, and playing rules (Hill-Haas, Dawson, Impellizzeri, & Coutts, 2011). Two teams compete in order to score a goal and, unlike isolated training drills, performance in the physical, technical, and tactical domain are simultaneously stressed (Dellal et al., 2012; Rampinini et al., 2007). In addition,

small-sided games are easy to implement in any training program, regardless of playing level or age, because this format can be adapted to the number of available players and space. Moreover, with specific manipulations this format can emphasize specific match situations to reach a particular training outcome. And finally, small-sided games can promote creative, exploratory, and tactical behavior (Santos et al., 2018). For these reasons, small-sided games are widely appreciated as a training tool to improve performance (Dellal et al., 2012) and optimize collective behavior (Davids, Araújo, Correia, & Vilar, 2013; Davids, Araújo, Hristovski, Passos, & Chow, 2012). Besides, small-sided games are embraced by many soccer associations, including the Royal Dutch Soccer Association (KNVB). The KNVB emphasizes small-sided games as a best practice to learn soccer by the credo "you learn to play soccer by playing soccer" (Tamboer, 2004, p. 133). The KNVB argues that players should practice the actions that occur during the match in a setting that resembles the match as much as possible, rather than in an isolated setting. Supported by a scientific and practical perspective, small-sided games allow players to practice their soccer specific actions and both teams to attack and defend in a setting that resembles the match.

In order to enhance the learning process, coaches manipulate small-sided games to emphasize and mimic match situations. This produces an infinity of small-sided game designs, in contrast to the fixed regulations of the official match. Coaches generally tend to reduce pitch size and number of players to create a situation in which players need to act quickly under the pressure of time. Besides their aim to enhance the decision-making skills by reducing the number of options (Davids et al., 2013), manipulating these task constraints also affects physical and technical performance (Glazier & Robins, 2013; Newell, 1986). In general, smaller pitch sizes or a decrease in player number result in less distance covered in total and at high intensity, and number of sprints (physical domain), and more individual ball involvements, interceptions, duels and tackles, but also less accurate passing (technical domain) (Aguiar, Botelho, Lago-Peñas, Maçãs, & Sampaio, 2012; Hill-Haas et al., 2011). Traditionally, soccer coaches use a typical small pitch for the number of players. These manipulations in pitch size and number of players influence a player's actions in small-sided games. However, the scientific literature lacks consistency in manipulations used in the designs of the small-sided games, which limits generalizability of the effects. Therefore, there is a need for a sound scientific background in order to evaluate the effects of manipulations on individual performance.

Manipulating small-sided games influence individual performance, but this might also have an impact on the tactical behavior of players and teams. Frencken et al. (2013) and Folgado et al. (2014) revealed that different pitch sizes and number of players, respectively, changed player dispersion and interaction patterns. Progress has

been made in recent years to overcome the difficulty of capturing tactical behavior. This has resulted in for example access to accurate tracking systems (Frencken, Lemmink, & Delleman, 2010; Ogris et al., 2012), big data, and (elite) soccer. In addition, the dynamic systems theory has become more accepted in soccer science to explore collective behavior. Both progressions facilitate soccer scientists to further investigate the effects of manipulations in small-sided games.

Representation

Originally, small-sided games were introduced as small-group play (Hoff, Wisløff, Engen, Kemi, & Helgerud, 2002). This is where the widely-used argument for playing small-sided games originated from: small-sided games represent (specific situations of) the official match. Supporting arguments for playing these training formats are that players employ a combination of physical, technical, and tactical performance and that teams alternate in attack and defense just like they do in the match. A small-sided game meets many of the requirements of a representative learning design, because it preserves features of the official match where players can i) select relevant affordances from cooperation with team members and competition with opponents and ii) act with similar soccer specific actions (Araújo & Davids, 2015). The format creates a training context with corresponding and meaningful behavior just like it occurs in the match: cooperation and competition between players within the constraints of soccer. A positive outcome of such design is that it suggests a positive transfer of skills from training to the match (Araújo & Davids, 2015). Small-sided games have a representative character for the match, which should facilitate the learning process of soccer.

At first sight, any random small-sided game resembles the match. Players within teams play together, players of opponent teams compete with each other, and all players use soccer specific actions during small-sided games, irrespective of the design. However, inherent to the definition of a small-sided game, coaches and scientists generally tend to use a smaller number of players and pitch sizes, different ratios in pitch length and width, and different game durations than the actual match that influences individual performance and team tactical behavior. As a result, players cover less distance, perform less high intensity activities and sprints, and interpersonal distances are smaller (Aguiar et al., 2012; Hill-Haas et al., 2011). This consequently affects technical requirements like passing, dueling, tackling, and intercepting the ball (Dellal et al., 2012). Besides, specific environmental characteristics are difficult to replicate, like playing in front of a crowd. Associated affective constraints, such as a consequence of winning or losing resulting in (perceived) match pressure, are often removed from a training environment in order to facilitate the learning process of soccer (Headrick,

Renshaw, Davids, Pinder, & Araújo, 2015). Despite widely claimed by researchers and practitioners, it is on debate whether the current use of small-sided games are a real representation of the official match.

Theoretically, the learning process in soccer would benefit from an optimal representation of the match. Yet, differences in predominantly pitch size and number of players in the current use of small-sided games result in different behavior compared to the match. From this point of view, a small-sided game is considered an optimal representation if individual performance and collective behavior measures are similar to the match. Stated in statistical terms that implicates no significant differences (with large effect sizes) between the match and small-sided game. A new perspective, like the relative pitch area (Casamichana & Castellano, 2010; Castellano, Puente, Echeazarra, & Casamichana, 2015), can contribute to optimization of small-sided games. The use of similar playing areas, playing rules, and possible other match constraints could facilitate that players can cooperate, compete, and act in a match-like environment. Therefore, based on concepts of a representative learning design, a constraint-led approach, previous research, and the vision of the KNVB for soccer practice, a model is proposed in which the representation of small-sided games for the official match is maximized (figure 1.2). Accordingly, such representative learning design implies enabling a positive transfer from the training to the match: behavior acquired in the training will be employed in the match.

Youth soccer

The age of a soccer player is of importance for the individual performance. Throughout their youth, players improve their physical, technical, and tactical performance as a result of development, training and playing matches (Reilly, Williams, Nevill, & Franks, 2000; Vaeyens, Lenoir, Williams, & Philippaerts, 2008; Williams, 2000). At various skill levels, different age groups show differences in individual performance and collective behavior in soccer. In general, an increase of age results in altered physical performance, evidenced by more distance covered and more high intensity activities, such as high intensity runs and sprints (Buchheit, Mendez-Villanueva, Simpson, & Bourdon, 2010; Goto, Morris, & Nevill, 2015). In addition, intra-team and inter-team distances are larger in older teams compared to younger teams in small-sided games (Folgado et al., 2014). These differences across age groups show the impact of age on soccer performance.

During their development towards an adult soccer player, young soccer players need to acquire the skills to cooperate. Therefore, small-sided games are a widely used training format in this learning process. Differences exist between young age groups in the way they play comparable small-sided games (Folgado et al., 2014), and

that there are differences in physical performance during match-play (Buchheit et al., 2010; Mendez-Villanueva, Buchheit, Simpson, & Bourdon, 2013). However, there is large variation in study designs: different small-sided game formats, age groups, and skill level limit the interpretability of the results. Research is needed to map differences across age categories in soccer. Most likely, different age groups respond differently to manipulations in small-sided games. Consequently, the relation between small-sided games and the official match is different across age groups. Therefore, in light of the learning process of soccer, it is important to investigate if small-sided games represent official matches in different age categories in elite youth soccer.

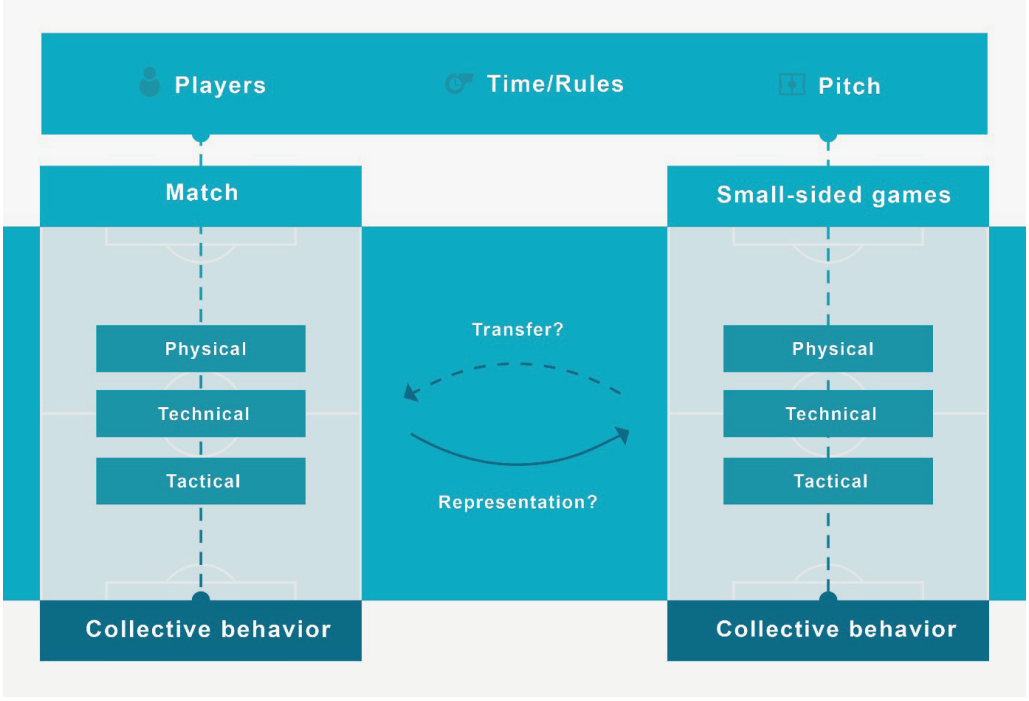

Figure 1.2. Small-sided games as a learning environment in order to represent the official match.

Thesis outline

This thesis' main objective is to determine if and how small-sided games represent the official match in elite youth soccer. The variables pitch size (using two relative pitch areas), number of players (varying from small to large teams), and age (varying from younger to older age categories) are investigated on their influence on small-sided

games. Further, the relation of these small-sided games with the match is determined. For the purpose of this thesis, talented soccer players from three Dutch professional youth academies participated. Pitch sizes (applying 120 m^2 and 320 m^2 relative pitch areas) and number of players (i.e., 5 vs. 5, 7 vs. 7, 9 vs. 9, and 11 vs. 11) were manipulated during small-sided games (figure 1.3). Playing rules of the official match were applied in the small-sided games. Official matches and small-sided games were played by four age categories (i.e., under-13, under-15, under-17, and under-19) in order to determine the performance and behavior in youth soccer. Positional data and video footage were collected in the matches and small-sided games to determine individual performance and collective behavior.

In chapter 2, the influence of age on team tactical behavior during small-sided games is examined. Two age groups, i.e. under-17 and under-19, play 5-a-side games on a 40 x 30 m pitch size. Team tactical behavior is determined with team tactical measures and interaction patterns.

In chapter 3, physical performance and team tactical behavior are examined in 5-a-side games played on a large and a small pitch across four age categories. Here, the concept of a match-derived relative pitch area (i.e., 320 m^2) is introduced which provides a comparable playing area as the match. A 'traditional' 120 m^2 relative pitch area is used for the small pitch.

In chapter 4, the match-derived relative pitch area is applied in 5-a-side, 7-a-side, and 9-a-side games. Team tactical behavior in these formats is compared with official matches in various age groups. Team tactical measures focus on intra-team distances with corresponding tactical variability. In addition, two-player and four-player sub-groups are used in order to compare team tactical measures in small-sided games with official matches.

In chapter 5, physical and technical performance along with team tactical behavior is compared in the official match and 11 vs. 11 training games. Match pressure may account for differences between training games and the official match, despite similarities in pitch size, number of players, and playing rules. Effects of this match pressure are investigated.

This thesis concludes with a general discussion of relevant outcomes, strengths and limitations of the studies, and implications for soccer practice and science that can guide future research.

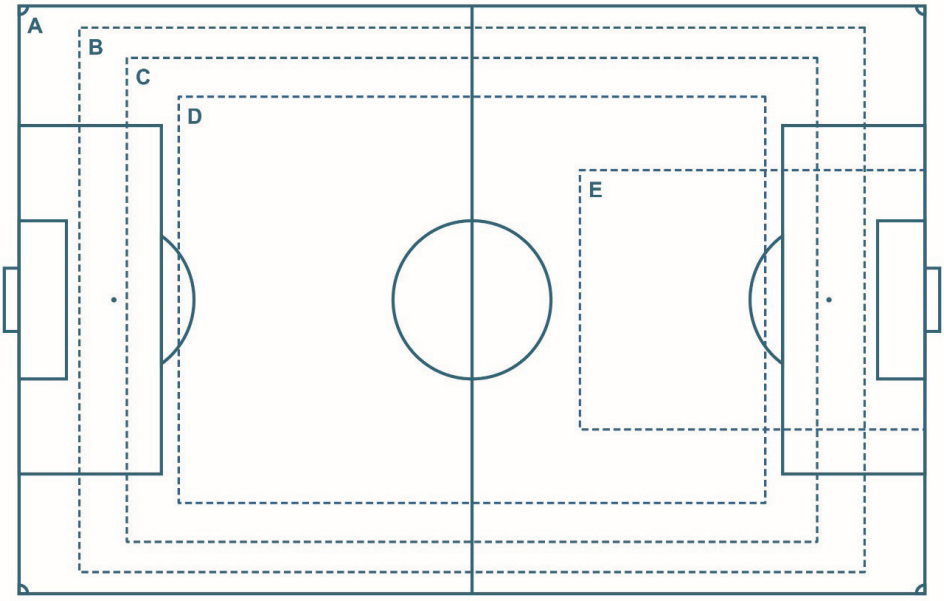

Figure 1.3. Pitch sizes used in this thesis for the A. official match and 11-a-side game (105 x 68 m), B. 9-a-side game (91 x 63 m), C. 7-a-side game (80 x 56 m), and 5-a-side games (D. 68 x 47 m and E. 40 x 30 m). Matches and small-sided games on pitches A-D are played on a match-derived relative pitch area (on average 320 m^2) and pitch E corresponds to a 120 m^2 relative pitch area.

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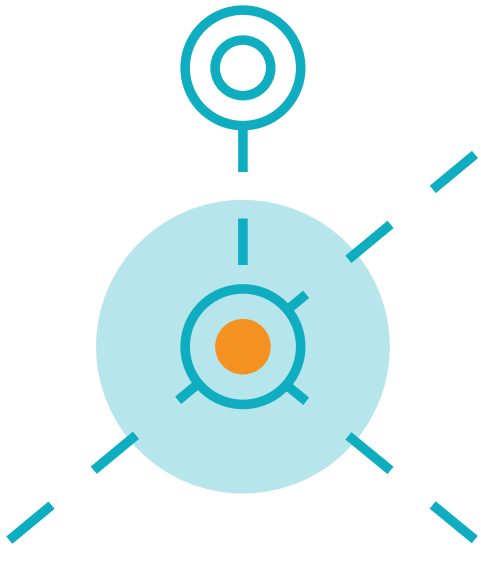

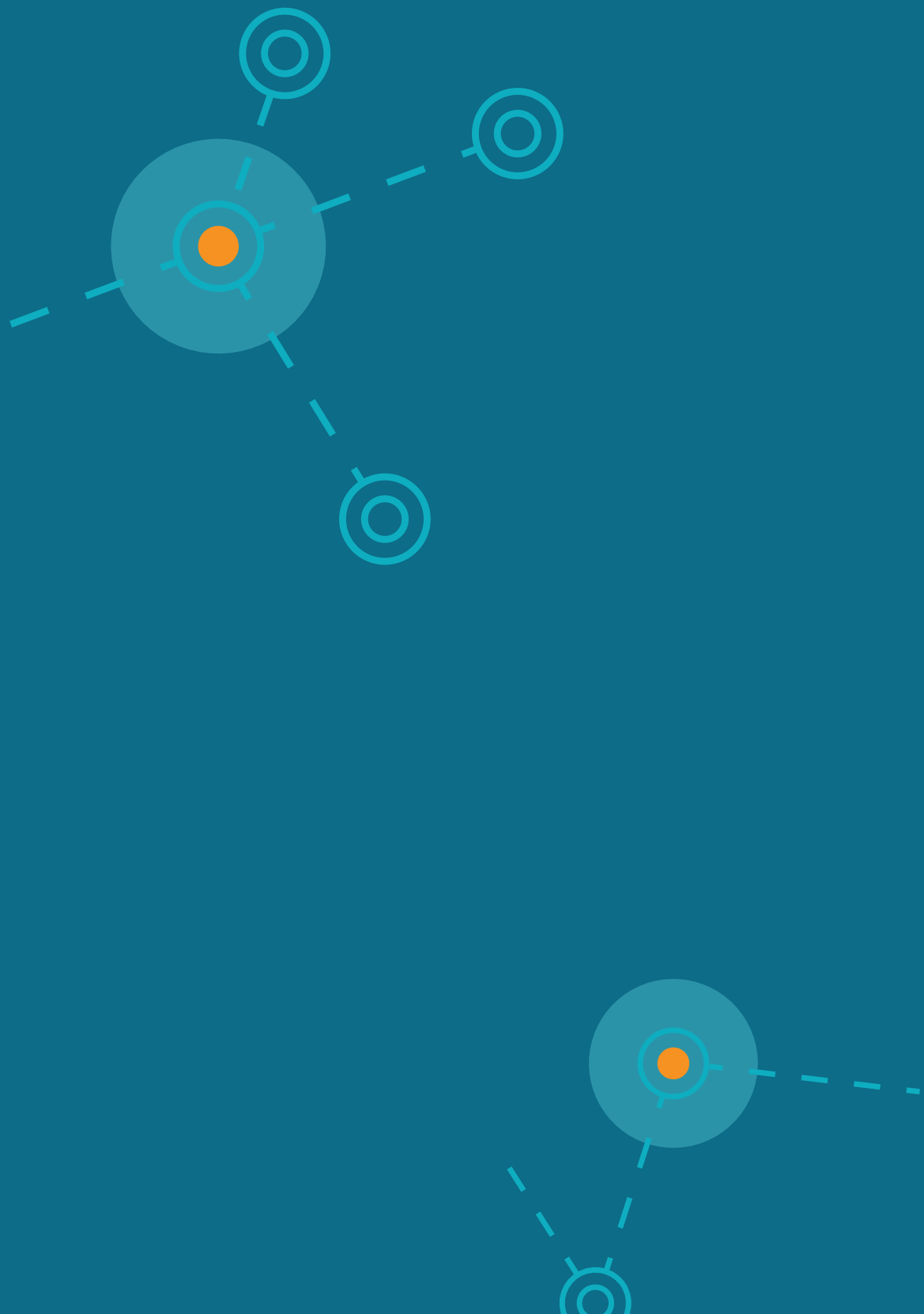

CHAPTER 2

The older, the wider: on-field tactical behavior of elite-standard youth soccer players in small-sided games

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Abstract

Purpose: Young soccer players need excellent tactical skills to reach the top. Tactical behavior emerges through interactions between opposing teams. However, few studies have focused on on-field tactical behavior of teams with talented soccer players. Therefore, this study aimed to determine teams' tactical behavior during small-sided games in two age categories, Under-17 and Under-19. Methods: Positional data of thirty-nine elite-standard soccer players were collected during twenty-four small-sided games to calculate longitudinal and lateral inter-team distances, stretch indices and length per width ratios. Corresponding interaction patterns and game-to-game variability were also determined.
Results: Under-19 showed a significantly larger lateral stretch index and a significantly lower length per width ratio compared with Under-17. Furthermore, teams of both age groups showed similar large proportions of in-phase behavior. Variability of tactical performance measures within and between games was similar for Under-17 and Under-19.
Conclusions: Variability within games seems to be functional for attacking teams for creating goal-scoring opportunities. In conclusion, the main difference was that Under-19 adopted a wider pitch dispersion than Under-17, represented by a larger lateral stretch index and smaller length per width ratio. Coach instructions and training exercises should be directed at exploiting pitch width to increase the pursuit of goal-scoring.

Key words: Dynamical systems, Tactics, Talent development, Performance analysis, Football

Introduction

Players are required to possess excellent tactical skills to perform at top level in their sports (Elferink-Gemser, Visscher, Lemmink, & Mulder, 2004; Kannekens, Elferink-Gemser, Post, & Visscher, 2009; Reilly, Williams, Nevill, & Franks, 2000). To practice and develop these skills, small-sided games are assumed to serve as an excellent training tool (Dellal, Hill-Haas, Lago-Peñas, & Chamari, 2011; Rampinini, Impellizzeri, et al., 2007). Small-sided games evoke movement patterns and requires decision making skills similar to performance under pressure and fatigue in a competitive environment (Gabbett & Mulvey, 2008). For a player to perform his action, time and spatial constraints in a small-sided game are similar in full-sized matches. Tactical behavior can be defined as the individual and collective actions of a team to best employ player skills in order to contribute to the team's goal of attacking and defending by goal scoring or preventing goals (Carling, Williams, & Reilly, 2005). It emerges through interactions with other players on the field (Bourbousson, Sève, & McGarry, 2010b). McGarry, Anderson, Wallace, Hughes, and Franks (2002) proposed two different types of interactions between players that occur during competition: inter-couplings reflect the competitive interactions between opponents and intra-couplings reflect the cooperative interactions between players within a team. Principles of the Dynamical Systems Theory were introduced to explain how these interactions influence the behavior of individual players (Grehaigne, Bouthier, & David, 1997) in individual sports situations like tennis and squash (e.g. McGarry et al., 2002; Palut & Zanone, 2005) and in team sports situations like basketball (Bourbousson, Sève, & McGarry, 2010a), rugby (Passos et al., 2011) and soccer (Frencken, Lemmink, Delleman, & Visscher, 2011; Travassos, Araújo, Vilar, & McGarry, 2011).

Besides interactions between individuals, interactions are also present between opposing teams (Bourbousson et al., 2010a; Frencken, Plaats van der, Visscher, & Lemmink, 2013). Several performance measures have been proposed to reflect tactical concepts at team level present in team sports. These tactical performance measures are derived from positional data of the players during matches. A first step was the conceptualization of the team centroid, which was calculated as the mean position of all outfield players (Frencken et al., 2011). From this, the inter-team distance (i.e., the distance between the centroids of opposing teams) was proposed to reflect the tactical concept of putting pressure of one team on the other (Frencken, Poel de, Visscher, & Lemmink, 2012). Bourbousson et al. (2010a) and Folgado, Frencken, Lemmink, and Sampaio (2014) conceptualized the stretch index and the length per width ratio, respectively, both determine the dispersion of the teams on the pitch. Whereas the stretch index is computed as the mean distance of the outfield players to the team centroid. Spatial-temporal patterns of such variables provide more detailed information on the type of

interaction between teams. Team centroids of opposing teams move mainly in the same direction over the pitch during small-sided soccer games (Frencken et al., 2011), during attacking situations near the scoring zone in small-sided soccer games (Duarte et al., 2012) and during parts of a basketball game (Bourbousson et al., 2010a). This interaction pattern of simultaneous movement in the same direction is called in-phase behavior of the opposing teams. When team centroids move in opposite direction, it is referred to as anti-phase behavior. In-phase pattern is reported to be dominant in small-sided games (Frencken et al., 2013) and full-sized matches (Frencken et al., 2012). So, several tactical performance measures offers insight in tactical behavior and interaction patterns.

Until now, it is unclear how these tactical performance measures change over consecutive small-sided games. In studies where on-field tactical performance measures were evaluated, participants played only one small-sided game per age group or per condition (Folgado et al., 2014; Frencken et al., 2013). However, it has been shown that physical activity profiles vary over consecutive games (Gregson, Drust, Atkinson, & Di Salvo, 2010; Rampinini, Coutts, Castagna, Sassi, & Impellizzeri, 2007). Gregson et al. (2010) found high between-match variability for high-speed activity over consecutive Premier League soccer matches, implying highly varying activity profiles across matches. This variability in activity profiles might be due to changes in technical and tactical requirements (Gregson et al., 2010). However, no conclusive evidence for tactical match-to-match variability is available. Given the match-to-match variability for physiological variables, it is likely that tactical performance measures also vary within and over consecutive games. This match-to-match variability has to be taken into account in the design of this study and tactical performance between small-sided games should be evaluated.

Next to variability over a series of small-sided games, tactical behavior is constrained by personal characteristics, such as age (Newell, 1986). These skills facilitate tactical behavior during games and are dependent on level of expertise and age (Kannekens et al., 2009; Roescher, Elferink-Gemser, Huijgen, & Visscher, 2010; Vaeyens, Lenoir, Williams, Mazyn, & Philippaerts, 2007). So far, tactical behavior on the pitch has only been determined in young amateur soccer players (Folgado et al., 2014). Positional data of three age categories (Under-9, Under-11 and Under-13) were collected during small-sided games. Distances between the centroid positions were similar across the age categories in a 4 vs. 4 condition, but Under-13 showed lower length per width ratios (i.e., length divided by width) compared with the younger age groups. It is suggested that older teams with talented players demonstrate different values in the length and width relation, which is represented by a wider dispersion on the field.

The main purpose of this study was to determine on-field tactical behavior of Under-17 and Under-19 soccer teams in a series of small-sided games. Tactical performance measures have been conceptualized to reflect tactical behavior on the

field, such as putting pressure on the opponent or the dispersion of players on the pitch. It was hypothesized that, as age increases, teams will play wider, displayed in a wider dispersion of players on the pitch.

Methods

Participants

Thirty-nine elite-standard male youth soccer field players (mean ± SD age 16.3 ± 1.2 years; length 174.5 ± 7.1 cm; body mass 67.6 ± 8.6 kg) playing at the highest level in The Netherlands participated in this study. Twenty-three players were assigned to Under-17 (age 15.4 ± 0.7 years; length 173.0 ± 7.5 cm; body mass 64.2 ± 8.0 kg) and sixteen to Under-19 (age 17.4 ± 0.7 years; length 176.7 ± 5.9 cm; body mass 72.6 ± 7.2 kg). Within each age group, the youngest players played against each other in sub categories and so did the oldest players. Every sub category played six small-sided games (four vs. four plus goalkeepers). Outfield players were randomly assigned to a team to balance the quality of the teams to control for differences in tactical quality. The composition of the teams changed over consecutive small-sided games. In total, twenty-four small-sided games were played. Players were familiar with this training routine, because small-sided games are commonly used exercises during regular training sessions. A 20-min warm-up containing exercises with and without the ball preceded the small-sided games. Players and coaches were unaware of the purpose of the study, minimizing alterations of player's tactical behavior. Players and coaches were instructed to win the game. Each player gave written informed consent before data collection and all procedures were in accordance with the ethical standards of the Medical Faculty of the University Medical Center Groningen, University of Groningen, The Netherlands.

Design

In line with previous protocols, an intermittent design with a work-rest ratio of 4:1 was adopted (Hill-Haas, Rowsell, Dawson, & Coutts, 2009), with a 6-min game duration. Games were played outdoors on natural grass on a 40 x 30 m (length x width) pitch. These dimensions were based on the opinion of two expert coaches, because it prevents that players try to score from every position on the field and it facilitates combination football that complies with the goal of this study. The goalkeepers defended a regular FIFA-approved goal of 7.32 x 2.44 m (width x height). Goalkeepers were restricted to two-touch play. The offside rule was not applied. Positional data of goalkeepers were not included in this study. Coaches were instructed to encourage and coach their teams similar to competitive match situations (Hill-Haas, Coutts, Rowsell, & Dawson, 2008; Hill-Haas et al., 2009).

Data collection

Positional data of each player were collected using the local position measurement (LPM) system (Inmotio Object Tracking BV, Amsterdam, The Netherlands). This is an accurate and valid instrument to record position and speed of players over time (Frencken, Lemmink, & Delleman, 2010; Ogris et al., 2012). To identify the position, players wore a vest with an antenna on each shoulder that was connected to a transponder on their back. A main base station transmitted a radio-frequency signal, received by the antennas. The individual information was sent by the transponder to ten base stations around the field. From there, the information was transmitted to the main server and computer. The sampling frequency per player was 43 Hz.

Data processing

Positional data were used to calculate the following tactical performance measures: centroid positions, longitudinal and lateral inter-team distances, longitudinal and lateral stretch indices and length per width ratio (lpwratio). The team centroid was determined as the mean longitudinal and lateral position of all outfield players (figure 2.1A). This team centroid represents the mean position of its players on the pitch. Distance between the team centroids, the inter-team distance, is conceptualized to represent the pressure of one team on the other team. Longitudinal and lateral inter-team distances were computed as the absolute distance between centroids of opposing teams (Frencken et al., 2012). The dispersion of players of a team on the pitch is determined as the stretch indices and length per width ratio. The stretch index was the mean distance of all outfield players within a team to the centroid position (figure 2.1B), calculated longitudinally and laterally (Bourbousson et al., 2010a). Length per width ratio was calculated based on the length and the width of the team. The length of the team is the distance between the players with the highest and lowest longitudinal position. The same was applied to calculate the width of the team in the lateral direction. Per sample, the ratio of the length and width was calculated (Folgado et al., 2014).

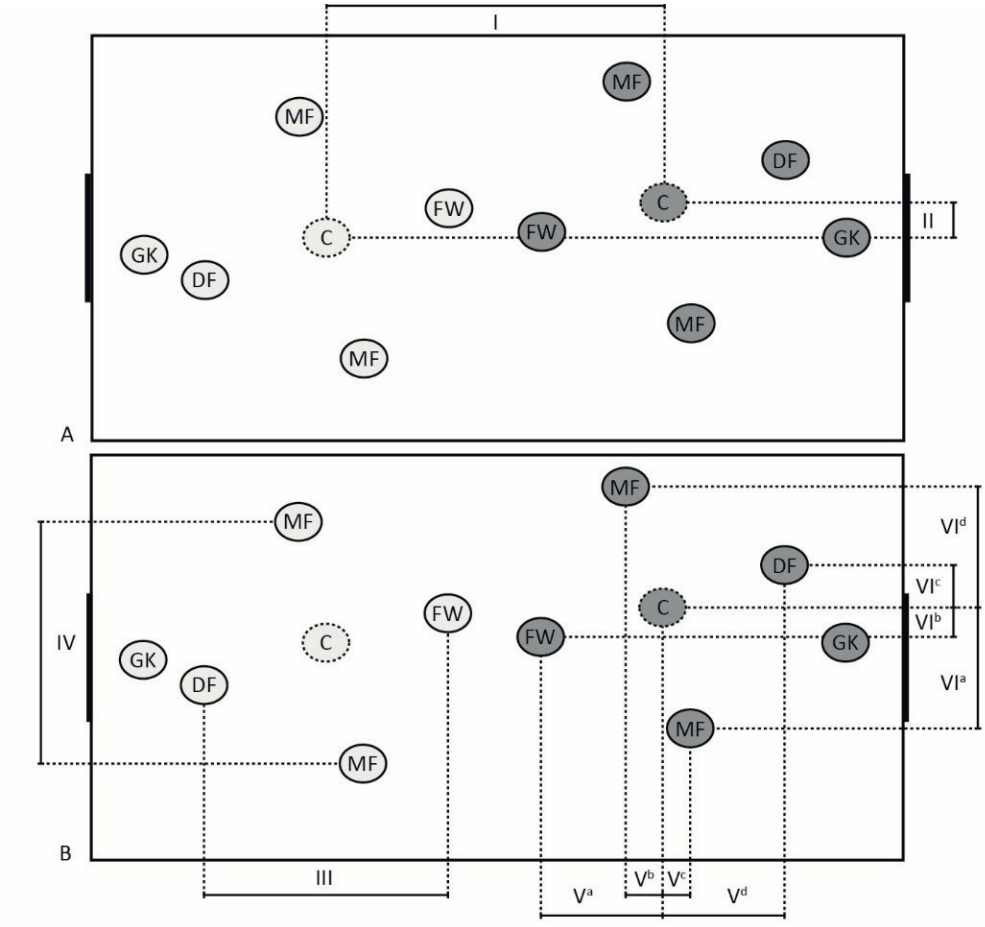

Figure 2.1. Representation of tactical performance measures of two opposing teams (goalkeeper [GK]; defender [DF]; midfielder [MF]; forward [FW]) and their centroid positions (C). In A) the representation of the inter-team distances (I) and in B) the representation of the lpwratio (length [II] and width [III]; length per width ratio = II/III) and stretch indices (mean longitudinal [IV^a, IV^b, IV^c and IV^d] and lateral [V^a, V^b, V^c and V^d] distance of all players to centroid).

Statistical analysis

Pearson correlation coefficients (*r*) were calculated for longitudinal and lateral centroid positions to determine a linear relationship between the opposing teams (Frencken et al., 2011). Means and standard deviations were calculated for inter-team distances, stretch indices and length per width ratios.

Running correlations were calculated for centroid positions, stretch indices and length per width ratios between the opposing teams over a moving 3-s window (Frencken et al., 2013). Correlations close to 1 correspond to in-phase behavior, while correlations close to -1 correspond to anti-phase behavior of opposing teams. Correlations near zero represent no consistency in the direction of the change and correspond with no pattern. The correlations were grouped to evaluate patterns qualitatively. Correlation values of .5 and higher were grouped and assigned to in-phase, correlations of .49 to -.49 were grouped and assigned to no pattern and correlations of -.50 and lower were grouped and assigned to anti-phase (Frencken et al., 2013).

Coefficients of variation (CV) were calculated per game to determine the magnitude of variation of the tactical performance measures over consecutive small-sided games (Gregson et al., 2010; Rampinini, Coutts, et al., 2007). For this purpose, the tactical performance measure's standard deviation was divided by its mean and expressed in percentages. Coefficients of variation were checked for presence of a trend, e.g., systematic increase or decrease in the percentage of coefficient of variation over the consecutive small-sided games. Because no trends were observed, means and minima and maxima are reported.

Distances, running correlations and coefficients of variation of the tactical performance measures were checked for normality. Assumptions were not violated. Since mean values were used, independent-samples t-tests were conducted across the two age categories to determine significant differences in the tactical performance measures (SPSS version 19.0.01, SPSS Inc., Chicago, USA). Cohen's d (*d*) was calculated to determine the effect sizes, whereas effect sizes around .2 are considered as a small effect, around .5 medium effect and around .8 large effect. Significance level was set at .05.

Results

Centroid positions of the opposing teams in both age categories showed high correlations in longitudinal direction (≥ .80). The mean Pearson correlation coefficient for Under-17 was .96 and for Under-19 .94. In general, correlations were lower laterally. Mean Pearson correlation coefficients in this direction were .85 for Under-17 and .79 for Under-19.

Longitudinal and lateral inter-team distances did not show significant differences between the age categories (table 2.1). The mean inter-team distances did not differ for Under-17 and Under-19. In contrast, Under-19 showed significantly larger lateral stretch indices than Under-17 ($p < .001$), while the mean distance in the longitudinal direction was not significantly different between age categories.

In addition, the length per width ratio was significantly smaller for Under-19 than for Under-17 ($p < .05$). Large effect sizes were found for the longitudinal inter-team distance ($d = .85$), lateral stretch index ($d = 2.65$) and the length per width ratio ($d = 1.17$).

Table 2.1. Mean (standard deviation) distances, t-value and effect size (Cohen's *d*) of inter-team distances, stretch indices and length per width ratio over twelve small-sided games for two age categories.

	Distances (m)			
	Under-17	Under-19		
	Mean (SD)	Mean (SD)	*t*	*d*
Inter-team distance				
Longitudinal	1.97 (.93)	2.17 (.31)	-1.48	.85
Lateral	1.51 (.16)	1.61 (.45)	-.52	.30
Stretch index				
Longitudinal	4.59 (.11)	4.57 (.17)	.31	.18
Lateral	5.03 (.07)	5.24 (.08)**	-4.58	2.65
Lpwratio	1.00 (.04)	.97 (.03)*	2.02	1.17

* significantly different from Under-17 ($p < .05$).

** significantly different from Under-17 ($p < .001$).

Interaction patterns of centroid positions, stretch indices and length per width ratios showed large proportions of in-phase behavior (figure 2.2). That is, team centroids were moving simultaneously in the same direction for more than 70% of the time during the small-sided games (figure 2.2A). Stretch indices of the opposing teams increased or decreased simultaneously for more than half of the small-sided game (figure 2.2B). Teams showed anti-phase behavior for the stretch indices in considerable large parts of the games (20% longitudinally and 25% laterally). This behavior means that one team increased their stretch index while the opponent decreased and vice versa. Similarly, teams were increasing and decreasing their length per width ratio together in the same direction for more than 50% of the time per small-sided game (figure 2.2C). In the remaining time, the teams showed no pattern (27%) or anti-phase behavior (20%). The two age categories did not significantly differ from each other in their interaction patterns.

Coefficients of variation, representing game-to-game variation, showed high mean percentages for all tactical performance measures (table 2.2). Percentages for inter-team distances and length per width ratio were near 50 or higher. Percentages above 30 were found for the stretch indices. This means that the tactical performance

measures showed a large variation within a game. However, the range of the coefficients was relatively small. This means that the same rate of variability of the performance measures occurred in consecutive small-sided games. Although, no significant differences were found between the two age categories in game-to-game variation, large effect sizes were established for the longitudinal and lateral stretch indices. Stretch indices of Under-19 showed larger game-to-game variation than Under-17's stretch indices. In addition, small standard deviations (less than 5%) were found for the interaction patterns of all tactical performance measures (figure 2.2).

Table 2.2. Mean (standard deviation), minimum and maximum, *t*-value and effect size (Cohen's *d*) coefficients of variation (CV) of inter-team distances, stretch indices and length per width ratio over twelve small-sided games for two age categories.

	Coefficient of variation (%)					
	Under-17		Under-19			
	Mean (SD)	Min.-max.	Mean (SD)	Min.-max.	*t*	*d*
Inter-team distance						
Longitudinal	63.7 (5.5)	56.0 – 70.4	68.3 (9.7)	58.4-86.9	-1.00	.58
Lateral	82.0 (5.9)	71.3 – 88.2	79.8 (6.7)	73.0-90.0	.62	.36
Stretch index						
Longitudinal	32.8 (1.1)	31.6 – 34.9	35.1 (2.7)	32.0-39.8	-1.92	1.11
Lateral	32.4 (1.0)	31.4 – 33.9	33.6 (1.9)	31.6-36.2	-1.44	.83
Lpwratio	50.9 (6.2)	42.7 – 57.4	49.8 (4.0)	44.5-55.7	.35	.20

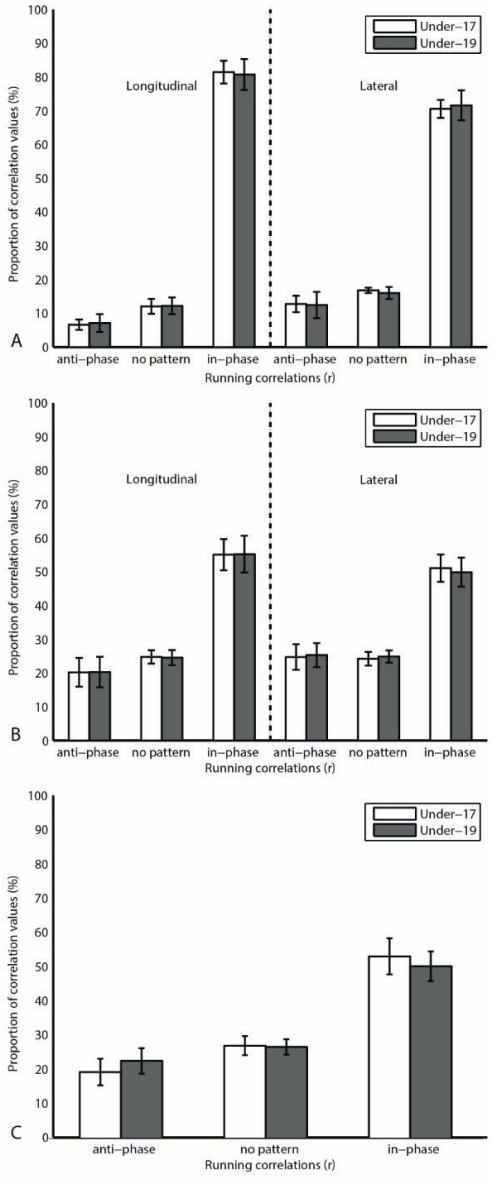

Figure 2.2. Histograms displaying the mean proportions of running correlations for Under-17 and Under-19 over twelve small-sided games of (A) team centroids in longitudinal and lateral direction, (B) stretch indices in longitudinal and lateral direction, and (C) length per width ratio.

Discussion

Tactical performance measures like the inter-team distances, stretch index and length per width ratio have been conceptualized to reflect tactical behavior on the field. In previous studies, tactical behavior was assessed through a questionnaire (Kannekens et al., 2009) or investigated with young players (13 years and younger) on the pitch (Folgado et al., 2014). This is the first study that investigated on-field tactical performance of elite-standard soccer players aged 14-18. Moreover, this is the first study investigating tactical behavior in a series of small-sided games. It aimed to determine on-field tactical performance measures in small-sided games of elite-standard soccer players in two age categories, Under-17 and Under-19, based on positional data.

In accordance with findings of Frencken et al. (2011), correlations of longitudinal and lateral team centroids showed strong positive linear relations with values above .80. Teams moved in the same direction over the field during the small-sided games, longitudinally and laterally. Correlations were higher longitudinally than laterally. These differences in linear relation were also previously established during small-sided games (Frencken et al., 2011, 2013). Longitudinal and lateral linear relations of the Under-17 age group were in accordance with the correlations of adult amateur soccer players (Frencken et al., 2011). Under-19 showed slightly higher correlations. High correlations of team centroids indicate that the two teams moved in the same direction over the pitch for a large part of time. Teams were tightly coupled while moving from goal to goal and from side to side. Similar findings were present in attacking behavior in small-sided games and in full sized matches. Duarte et al. (2012) found high correlations between centroid positions during specific attacking situations in 3 vs. 3 small-sided games. Centroid positions of the attacking and defending team decreased uniformly to the defensive line during sub-phases near the scoring zone. In full-sized matches, team's centroid positions were tightly coupled throughout the match (Frencken et al., 2012). Overall, correlations of the centroid positions in the present study were in line with the collective behavior of soccer players as reported in previous studies regarding small-sided games and full-sized matches, which indicates the representativeness of the small-sided games in this study.

As hypothesized, inter-team distances were not significantly different between the two age categories. Distances between the centroid positions of the teams did not differ between Under-17 and Under-19. Earlier observations reported similar mean inter-team distances in a small-sided game (4 vs. 4) for the Under-9, Under-11 and Under-13 age group (Folgado et al., 2014). However, present longitudinal inter-team distances were smaller than for the younger age categories. Possibly, a different performance level and pitch size explain these differences. In the current study, players of an elite-standard level played small-sided games on a 40 x 30 m pitch, while players in the

study of Folgado et al. (2014) played at an amateur level and played small-sided games at a 30 x 20 m pitch. Differences in performance level were found in self-reported tactical skills (Kannekens et al., 2009). Youth players who became adult professional soccer players showed better self-assessed tactical skills than soccer players who became adult amateur players. In addition, Frencken et al. (2013) reported that an increase in pitch length and width resulted in an increase of the inter-team distance longitudinally and laterally, respectively. In the current study, the combination of a higher performance level of the soccer players and larger pitch size in length and width might result in lower longitudinal inter-team distances. Although teams played on a larger pitch area, teams tend to put more pressure on the opposite team, which was reflected by a smaller distance between the team centroids. So, it seems that older soccer players of a higher performance level have better decision making skills, despite they have less time and less space. This warrants future research where similar pitch dimensions and performance level are controlled for to establish differences or similarities in inter-team distances across age categories.

The lateral stretch index was significantly larger for Under-19 than for Under-17 and means a larger lateral distance between players and a team's centroid for Under-19 than for Under-17. In contrast, the longitudinal stretch index was not significantly different between both age groups. Together, this infers a similar longitudinal dispersion of players on the pitch, but a larger lateral dispersion. The significant smaller length per width ratio supports this. Large effect sizes of the lateral stretch index and length per width ratio indicate large meaningful differences between the age categories in pitch dispersion. Under-19 players might be more aware of the opportunities the lateral direction offers for creating space for advancing up the field or goal-scoring opportunities, while these players were better able to detect these opportunities because of improved perceptual and cognitive skills (Williams, 2000). Improved physical skills could enable these players to exploit these opportunities and increase the lateral dispersion in relation to the younger players (Roescher et al., 2010). The increased lateral stretch index and a lower length per width ratio reflected this behavior for Under-19 in the present study. A decrease in length per width ratio was also previously observed in younger age categories (Folgado et al., 2014). It was argued that Under-13 players used the length of the pitch less than Under-11 and Under-9 players and therefore moved slower to the opposite goal. Taking the current results together, lower length per width ratio and a larger lateral stretch index indicate that the Under-19 age group adopted a wider dispersion on the pitch. Apparently, Under-19 players exploit the opportunities in the lateral direction of the pitch to disturb the stable system where teams were tightly coupled in the longitudinal direction. Under-19 players probably used improved physical, technical and visual skills to detect these

opportunities and exploit the width of the pitch to turn them into goal-scoring opportunities. It is important to consider the age-related differences between age categories in tactical behavior. Coaches should take these differences into account in their training design.

Next, interaction patterns were identified for both age categories. All tactical performance measures showed large proportions (more than 50%) of in-phase behavior. The interaction behavior was similar for Under-17 and Under-19. Frencken et al. (2013) established proportions of correlation values of centroid positions in adult amateur soccer that were slightly smaller (~5%) than the current correlation proportions. Different performance levels might have influenced these differences, as Frencken et al. (2013) suggested that centroid positions of amateur teams were less coupled due to less anticipation skills. As elite-standard soccer players might be stronger coupled, their interaction patterns presumably show more in-phase behavior. In addition, large proportions of anti-phase behavior were present for stretch indices and length per width ratios. This anti-phase behavior might have occurred during the transition of ball possession of the team to ball possession of the opponent. Teams were inclined to increase their dispersion during ball possession, while the opponent players decreased their dispersion. It is likely to assume that teams showed anti-phase behavior in parts of the game where transitions of ball possession took place. Travassos et al. (2011) suggested that ball possession influenced the aim of the attacking team to increase space and defending team to reduce space. However, the appearance of different interaction patterns needs further investigation with the focus on ball possession to offer more insight in the team's interaction patterns during (transitions of) ball possession. Identifying interaction patterns in attack and defense is useful in determining individual's contribution to the team strategy. This would be valuable in talent development programs, where it is important for a talented player in developing tactical skills and employ these skills for the overall team goal of attacking and defending by goal scoring or preventing goals.

Coefficients of variation were calculated to determine within game variability and standard deviations were calculated to establish game-to-game variability of tactical performance measures and interaction patterns respectively. Large coefficients of variation were observed for tactical performance measures in consecutive small-sided games, indicating large variability within a game. Small standard deviations (less than 5%) were found for interaction patterns of these performance measures. This indicates stable interaction patterns over consecutive games. Although large in-game variability of tactical performance measures was reported, Under-17 and Under-19 showed small game-to-game variability. Differences between Under-17 and Under-19 were not significant, but large effect sizes were found for the stretch indices, indicating

meaningful larger variation in the stretch indices for Under-19 than for Under-17. Under-19 showed larger variation in their stretch index longitudinally and laterally during a small-sided game. Large variability represents the interchanging attacking and defending behavior of opposing teams (Frencken et al., 2011) which seems to be functional for the attacking team in order to explore options in attack. Moreover, it allows the defending team to respond to these attacking explorations. The low game-to-game variability indicates that this functional variability is consistent over consecutive games. High variability within games is associated with critical events right before goal scoring or goal scoring opportunities. Duarte et al. (2012) found a change in position of the longitudinal team centroids in situations near the scoring zone. This crossing of centroid positions occurred especially right before the assistant pass was given and a goal was scored. In addition, Frencken et al. (2011) found crossings in situations prior to a goal is scored in small-sided games. Variability of tactical performance measures within a game might be functional for the attacking team to create goal-scoring opportunities. For the defending team, it is the challenge to restrict this variability as much as possible to prevent that the attacking team approaches the goal and creates a goal-scoring opportunity. Previously, game-to-game variability was established individually in activity profiles to determine fitness of soccer players (Gregson et al., 2010; Rampinini, Coutts, et al., 2007). Game-to-game variability of tactical performance seems to provide insight in functional variability for attacking behavior. Current results indicate functional variability within games. This functional variability is comparable over a series of small-sided games. Coach instructions during training and matches should focus on exploiting tactical variability which might lead to goal-scoring and goal-scoring opportunities.

Conclusions

The present study investigated tactical performance measures in small-sided games, using elite-standard youth soccer players in two different age categories. On-field tactical behavior has not been investigated before in players aged 14-18. Differences in the age categories were only present in tactical performance measures representing dispersion on the field. The Under-19 age group showed a wider pitch dispersion than the Under-17 age group, represented by a larger lateral stretch index and smaller length per width ratio. Future research should focus on a combination of tactical, perceptual and physical skills that might be an explanation for these differences in age categories. In addition, game-to-game variability was similar for the two age categories. In sum, the main change in on-field tactical behavior for older teams is that they make more use of the width of the pitch. Coaches of youth soccer teams should be aware of these

tactical differences between age categories in designing training practices. Besides, game-to-game variability offers insight in the variability of tactical performance measures within and over consecutive small-sided games. Training exercises and coach instructions to young soccer players should focus on exploiting pitch width during ball possession and increasing the variability of attacking behavior during the game to improve performance. Identification of interaction patterns is useful in talent development, for determining the individuals contribution to the overall team strategy.

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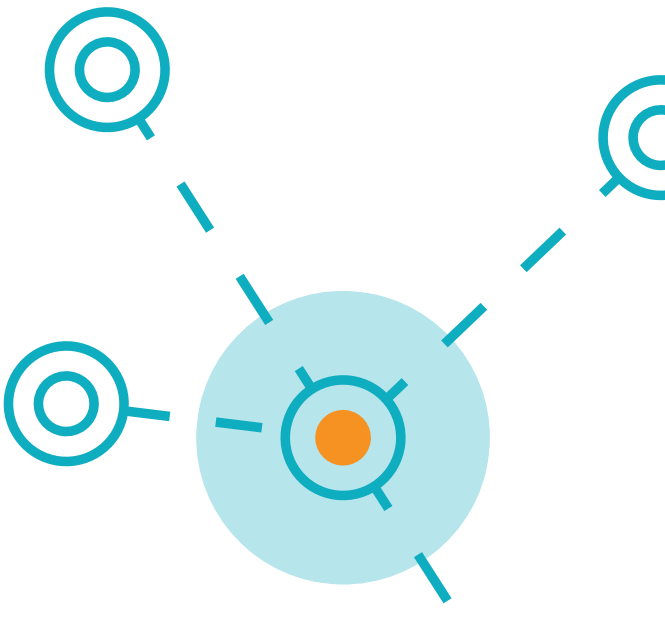

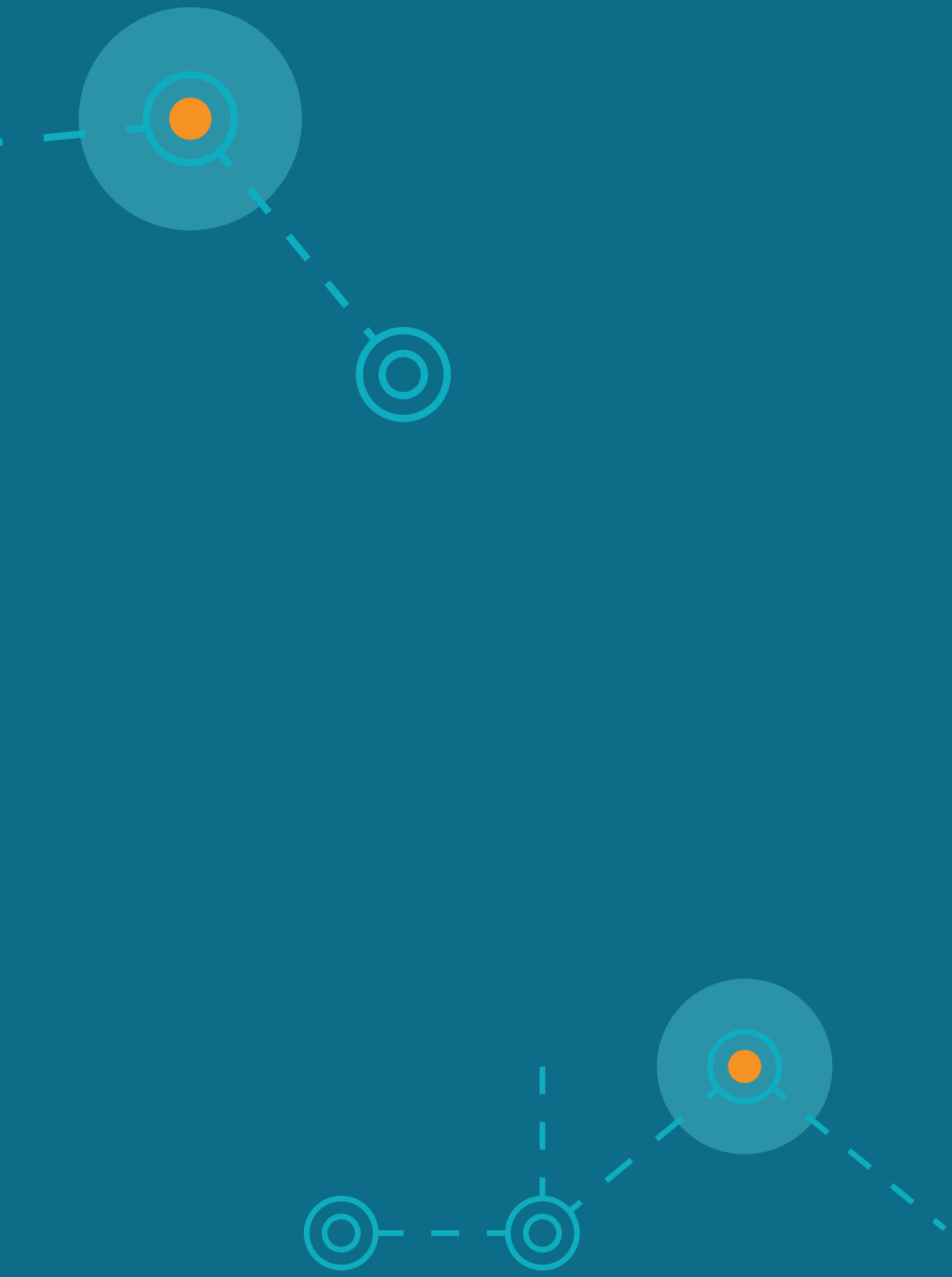

CHAPTER 3

Match-derived relative pitch area changes the physical and team tactical performance of elite soccer players in small-sided soccer games

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Abstract

Small-sided games (SSGs) are used in training sessions to prepare for full-sized matches. For the same number of players, smaller pitch sizes result in decreased physical performance and shorter interpersonal distances. A relative pitch area derived from the full-sized match results in larger pitch sizes and this may increase the fit between SSGs and full-sized matches. This study aimed to investigate SSGs with a traditional small pitch and a match-derived relative pitch area in youth elite soccer players. Four age categories (under-13, under-15, under-17 and under-19) played 4 vs. 4 plus goalkeepers on a small (40x30m, 120m^2 relative pitch area) and large pitch (68x47m, 320m^2 relative pitch area). The number of games per age category ranged 15-30. Positional data (LPM-system) were collected to determine physical (total distance covered, high intensity distance and number of sprints) and team tactical (inter-team distance, LPW-ratio, surface area, stretch indices, goalkeeper-defender distance) performance measures and tactical variability. On a large pitch, physical performance significantly increased, inter-team and intra-team distances were significantly larger and tactical variability of intra-team distance measures significantly increased. The match-derived relative pitch area is an important training manipulation and leads to changes in physical and tactical performance 4 vs. 4 plus goalkeepers.

Keywords: Football; talent development; task constraints; time motion analysis; ball possession

Introduction

Small-sided games (SSGs) are typically played on reduced pitch dimensions, with a lower number of players and often with adapted playing rules (Hill-Haas, Coutts, Rowsell, & Dawson, 2008). A SSG is preferred over isolated drills as a training form in soccer, because of its similarity with full-sized matches. SSGs replicate the complexity of interaction with team members opponents, and the ball, while two teams have the opportunity to score (Aguiar, Botelho, Lago, Maçãs, & Sampaio, 2012). Both contain the attacking and defending flow and players need to take quick decisions in an ever-changing environment and make optimal use of their physical, technical and tactical abilities to perform (Gabbett & Mulvey, 2008). Therefore, SSGs are widely used to develop and improve soccer skills and prepare for the full-sized match, regardless of playing level or player's age. Manipulating task constraints in SSGs has proven to elicit a major influence on player's soccer performance. In particular, manipulating pitch size and number of players lead to changes in physical load (Casamichana & Castellano, 2010; Hodgson, Akenhead, & Thomas, 2014; Rampinini et al., 2007), frequency and rate of successful technical actions (Aslan, 2013; Casamichana & Castellano, 2010; Hodgson et al., 2014) and team tactical performance (Folgado, Lemmink, Frencken, & Sampaio, 2014; Frencken, Plaats van der, Visscher, & Lemmink, 2013; Silva et al., 2014; Vilar, Duarte, Silva, Chow, & Davids, 2014).

Pitch size manipulations are widely investigated in previous research, where pitch sizes are often expressed in the relative pitch area: the surface area of the pitch divided by the number of players to improve comparability between SSGs (Casamichana & Castellano, 2010; Castellano, Puente, Echeazarra, & Casamichana, 2015). In contrast to a full-sized match relative pitch area of approximately 320m^2, many SSGs are played on a pitch with a relative pitch area of 150m^2 or less (see for a review Aguiar, Botelho, Lago, Maçãs, & Sampaio, 2012; Hill-Haas, Dawson, Impellizzeri, & Coutts, 2011). This results in a high player density and less time and space for players to make decisions when holding the ball and less space to run. In contrast, it is easier to make a duel or mark an opponent, because of the short interpersonal distance (Aguiar et al., 2012). In terms of physical performance, players typically covered less distance in total (Castellano et al., 2015; Owen, Wong, Paul, & Dellal, 2014), although Casamichana, Castellano, & Castagna (2012) showed an opposite effect. In addition, players covered more distance in high or sprinting speed zones in SSGs compared to (friendly) full-sized matches (Casamichana et al., 2012; Castellano et al., 2015; Owen et al., 2014). No or very little distance was sprinted in most of the SSGs. Additionally, a higher occurrence for duels, lost balls and a lower percentage for successful passes and ball possessions was observed in conditioned SSGs, although these were played as possession games with supportive players (Dellal et al., 2012).

Thus far, small pitch sizes in SSGs have led to different physical and technical demands than the full-sized match. Yet, Araújo & Davids (2015) advocate an adequate sampling of the match to create a representative learning environment. Therefore, characteristics of small-sided games, such as pitch size, should be considered carefully to meet training outcomes and stay close to match demands. A pitch with a relative pitch area derived from the full-sized match can increase the fit between training and match performance. Then, players have a relative playing area similar to a match that allows more attacking and defending exploration and organization. This affords teams to follow the natural flow of the game: free-up space in ball possession and tie-up space when ball possession is lost with continuously changing interpersonal distances as a consequence (McGarry, Anderson, Wallace, Hughes, & Franks, 2002) and leads to more tactical variability. Castellano et al. (2015) applied such match-derived relative pitch area in several SSGs and investigated players' physical performance. In 7- and 9-a-side games with a 300m^2 relative pitch area, players covered total distance and in higher speed zones similar to 11-a-side games. Moreover, more distance was covered in total and in higher speed zones compared to games played on a relative pitch area of 100 and 200m^2. As long as the relative pitch area was similar as the full-sized match, a different number of players did not influence the physical performance. This emphasizes the relevance of a match-derived relative pitch area in SSGs, but the research to this effect is limited to one study and an under-13 team.

Findings of this young age group on a relative pitch area of 300m^2 might not be generalizable to older age groups, as previous research proved that physical and team tactical performance change with increasing age. Older soccer players covered more distance in total and in high speed zones in studies concerning age groups ranged 11-16 and 13-18 year (Buchheit, Mendez-Villanueva, Simpson, & Bourdon, 2010; Goto, Morris, & Nevill, 2015). However, these differences were not observed in younger soccer players aged 13-15 years (Atan, Foskett, & Ali, 2016). Besides, team tactical performance changes as age increases. Intra- and inter-team distances and team tactical behaviour changed when soccer players are older (Barnabé, Volossovitch, Duarte, Ferreira, & Davids, 2016; Folgado et al., 2014; Olthof, Frencken, & Lemmink, 2015). Under-13 soccer players showed lower length-per-width values and higher inter-team distances than younger age groups in SSGs (Folgado et al., 2014). Supportive findings were present in team dispersion in SSGs for age categories under-17 and under-19 (Barnabé et al., 2016; Olthof et al., 2015). Altogether, age influences soccer performance, both physically and tactically. In sum, current research is fragmented in age groups, performance measures and pitch sizes. There is a need for research that investigates pitch size manipulation of a match-derived relative pitch area across a larger range of age groups on physical, technical and team tactical performance in elite soccer players.

While small pitch sizes result in different physical demands in SSGs, large pitch sizes might increase the physical demands. A match-derived relative pitch area is likely relevant for the team tactical behaviour as well, because players have similar time and space on the pitch as in a full-sized match situation. Therefore, the aim of this study is to determine the physical performance and team tactical behaviour in 4 vs. 4 plus goalkeepers played on a traditional small pitch and on a pitch with a relative pitch area of the full-sized match. The hypothesis is that, as a response to an increased pitch size, physical performance in high speed zones and inter- and intra-team tactical performance measures will increase. In addition, age groups are likely to respond differently to both SSGs.

Methodology

Participants

In total, 148 players (125 outfield players and 23 goalkeepers) from three Dutch professional youth soccer academies participated in this study and were assigned to the under-13, under-15, under-17 or under-19 age group. Each team played five bouts of a 4 vs. 4 plus goalkeepers SSG on a small pitch and five bouts on a large pitch . Each format of the small-sided game was played in a separate training session (see table 3.1). Players were assigned to a team according to the coach's perception to equally balance the quality of the teams. Substitutions were only allowed between the games to create randomness in the composition of the teams or in case of an injury suffered during the SSG. All players were notified of the purpose of the game. Players and their parents or legal guardians signed an informed consent. All procedures were in accordance with the standards of the local ethical committee of Human Movement Sciences of the Medical Faculty of the University Medical Center Groningen, University of Groningen, the Netherlands.

Table 3.1. Number of teams and players participating in the SSGs.

	SSGs	Clubs	Players	Age (years) (mean ± SD)
Under-13	20	2	36	12.5 ± 0.5
Under-15	30	3	43	14.4 ± 0.5
Under-17	15	2	28	16.6 ± 3.2
Under-19	25	3	43	17.9 ± 1.0

Design

The small pitch equals 40x30m, as this is often used during practice and in previous studies (e.g. Faude, Steffen, Kellmann, & Meyer, 2014; Hodgson et al., 2014; Kelly & Drust, 2009; Olthof et al., 2015). The relative pitch area is 120m^2. Pitch dimensions of the large pitch are derived from the 11 vs. 11 full-sized match (i.e. 100x70m). The relative pitch area in a full-sized match is 320m^2. This area is also applied to a SSG with 4 vs. 4 plus goalkeepers and equals 68x47m pitch size. The penalty box was proportionally reduced in both games and goals were official FIFA-approved goals (7.32x2.44m). All games were played on an artificial turf pitch.

Each SSG had a duration of 4 minutes. A 4-minute rest period between SSGs provide an optimal recovery (Köklü, Alemdaroglu, Dellal, & Wong, 2015). Each team started in the same formation of 1 goalkeeper, 1 defender, 2 midfielders and 1 attacker. This formation was chosen based on the opinion of expert coaches, to ensure that teams played in 4 lines and to control for possible different team strategies based on starting formation. Coaches were instructed to coach their players similar to a competitive match (Hill-Haas et al., 2008; Hill-Haas, Rowsell, Dawson, & Coutts, 2009). The purpose of each SSG was to win by scoring more goals than the opponent.

Playing rules of the SSG on a large pitch were in accordance with those of a full-sized competitive match. That is, the offside rule was applied and a kick-off from the centre spot took place at the start and after each goal. In contrast, during the small pitch SSGs, the offside rule was not applied, because of the limited dimensions and in accordance with the rules in previous studies. After a goal, the goalkeeper restarted the game with a goal kick.

Data collection

Positional data of all players were collected with the Local Position Measurement (LPM) system (Inmotio Object Tracking BV., Amsterdam, the Netherlands). Validation studies established that this is a valid instrument to accurately obtain x- and y-coordinates of each player on the pitch with a high sampling frequency of 1000 Hz divided by the number of transponders on the pitch (Frencken, Lemmink, & Delleman, 2010; Ogris et al., 2012). Each player wore a vest during the SSGs and positional data was collected with a minimum sampling frequency of 42 Hz and a maximum sampling frequency of 100 Hz.

In addition, videos were recorded with one or two HD video dome cameras (Bosch GmbH., Stuttgart, Germany) and one or two high resolution digital cameras (Canon HF100, Canon Inc., Tokyo, Japan; JVC Everio, JVC Kenwood Corporation, Kanagawa, Japan). Videos were automatically synchronized with the positional data in the LPM-software. Markers for the start and end of each SSG were placed based on audio-visual inspection of the videos.

Data processing

Game characteristics were determined with notational analysis using the video recordings. Number of transitions and duration of ball possession sequences, set pieces and number of goals and shots were counted per SSG. A team was in ball possession when it was in control over the ball (Collet, 2013). When the opposition won and was in control of the ball by at least one deliberate touch, a transition took place. Time of ball possession was determined as duration of a ball possession sequence. Set pieces were determined as any type of action to return the ball into play by means of a throw in, corner kick, goalkeeper kick and kick off. Any attempt to score a goal was taken together to determine the frequency of goals and shots (Rampinini, Impellizzeri, Castagna, Coutts, & Wisløff, 2009). A study on an unpublished dataset performed on the game characteristics revealed a inter-rater reliability of .89 (Cohen's K) for number of transitions, .92 (Pearson's R) for duration of ball possession and 100% agreement for set pieces and number of goals and shots.

Physical performance per player was computed with the positional data. Total distance covered per minute, distance covered at high intensity (HID, ≥ 19.8 km/h) and number of sprints (frequency of displacements ≥25.2 km/h) were quantified for every player (Abt & Lovell, 2009). Speed thresholds are kept similar for all age categories to compare physical performance between age groups (Goto et al., 2015).

Positional data were also used to calculate tactical performance measures in Matlab R2015b (The MathWorks, Inc., Natick, MA, USA). Centroid positions were determined as the average position of the outfield players and were used to calculate longitudinal (X) inter-team distances (Frencken et al., 2013). This is an indication of the pressure of one team on the other. Length and width were calculated and used to determine the length-per-width (LPW) ratio per team (Folgado et al., 2014). This ratio is a measure of the shape of the team. Total surface area is the area of the convex hull (Frencken, Lemmink, Delleman, & Visscher, 2011). The stretch index is the mean distance of each outfield player to the team centroid in either longitudinal and lateral (Y) direction (Bourbousson, Sève, & McGarry, 2010). Together with the surface area, the stretch indices are an indication of the size of the team. Goalkeeper (GK)-defender distance represents the space between goalkeeper and defending line.

Statistical analysis

Values of the game characteristics, physical and team tactical performance measures were checked for their normality. Assumptions were not violated. Then, means and standard deviations were calculated for each age category per SSG with Matlab R2015b. A MANOVA (Pillai's Trace) was conducted to test the significant differences in pitch size using R for Windows 324 (R Foundation for Statistical Computing, Vienna, Austria). Coefficients of variation of team tactical performance measures were used to investigate tactical variability. Differences were tested to evaluate differences in type of SSG and age group. Significance level was set at 5%. Effect sizes were determined by calculating partial eta-squared (η_p^2)(Levine & Hullett, 2002). Effect sizes are considered as small ($\eta_p^2<.06$), moderate ($.06\leq\eta_p^2<.15$) or large ($\eta_p^2\geq.15$) (Cohen, 1988).

Results

A significant main effect of pitch size was observed for all game characteristics ($F=18.56$; $p<.01$), physical performance ($F=141.15$; $p<.01$) and team tactical performance ($F=192.71$; $p<.01$). Less transitions, organized ball possessions and goals/shots resulted in a longer duration of ball possession on a large pitch (table 2). In addition, physical performance was higher on a large pitch, expressed as more distance covered ($F=194.24$; $p<.01$; $\eta_p^2=.22$), more HID ($F=364.44$; $p<.01$; $\eta_p^2=.34$) and a higher occurrence of sprints ($F=106.12$; $p<.01$; $\eta_p^2=.13$; figure 3.1). Inter-team distance ($F=358.00$; $p<.01$; $\eta_p^2=.68$), LPW-ratio ($F=17.83$; $p<.01$; $\eta_p^2=.10$), longitudinal ($F=225.57$; $p<.01$; $\eta_p^2=.57$) and lateral stretch index ($F=112.92$; $p<.01$; $\eta_p^2=.40$), surface area ($F=215.15$; $p<.01$; $\eta_p^2=.56$) and GK-defender distance were also significantly larger on a large pitch ($F=347.85$; $p<.01$; $\eta_p^2=.67$, figure 3.2). Moderate to large effect sizes were observed for all variables.

Significant interaction effects (pitch size*age category) were found for physical (F=4.37; p<.01) and team tactical performance (F=3.17; p<.01). With older age, there was more HID (F=5.16; p<.01; η_p^2=.02) and more sprints were conducted on a large pitch (F=5.25; p<.01; η_p^2=.02, figure 3.1). In addition, inter-team distance (F=7.90; p<.01; η_p^2=.12) and GK-defender distance (F=3.34; p<.05; η_p^2=.06) increased with older age on a large pitch, longitudinal stretch index (F=3.05; p<.05; η_p^2=.05) decreased on a large pitch and lateral stretch index (F=2.82; p<.05; η_p^2=.05) and surface area (F=4.37; p<.01; η_p^2=.07, figure 3.2) increased on a small pitch. Observed effects were small, with a moderate effect for inter-team distance and surface area.

Table 3.2. Game characteristics (mean and standard deviation) of SSGs played on small and large pitches in four age categories. Test statistics and effect sizes are presented for main effect of pitch size.

		under-13		under-15		under-17		under-19				
		Small	Large	Small	Large	Small	Large	Small	Large	F	p	η_p^2
Transitions	Mean	24.20	17.80	25.33	17.53	22.20	13.50	27.40	16.10	66.48	.01	.45
	SD	8.19	5.96	6.66	4.12	3.27	2.92	4.78	2.33			
Ball possession (s)	Mean	10.70	13.19	9.03	11.50	10.66	15.42	8.54	13.74	32.71	.01	.29
	SD	4.02	5.98	2.56	2.42	1.19	3.48	1.59	2.55			
Set pieces	Mean	6.00	4.00	6.87	3.67	5.80	2.30	7.20	4.30	46.76	.01	.36
	SD	2.40	2.00	2.67	1.99	1.48	1.49	2.51	1.34			
Goals/shots	Mean	7.80	4.00	8.33	5.00	7.00	5.00	8.67	6.40	35.02	.01	.30
	SD	3.55	1.63	2.74	2.00	1.22	1.49	3.44	1.17			

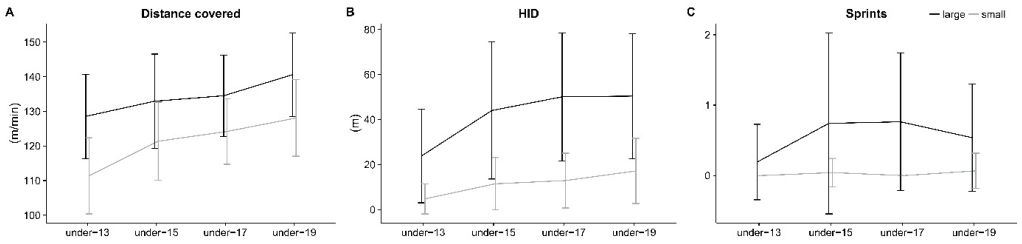

Figure 3.1. Physical performance (mean ± standard deviation) in SSGs played on small and large pitches in four age categories.

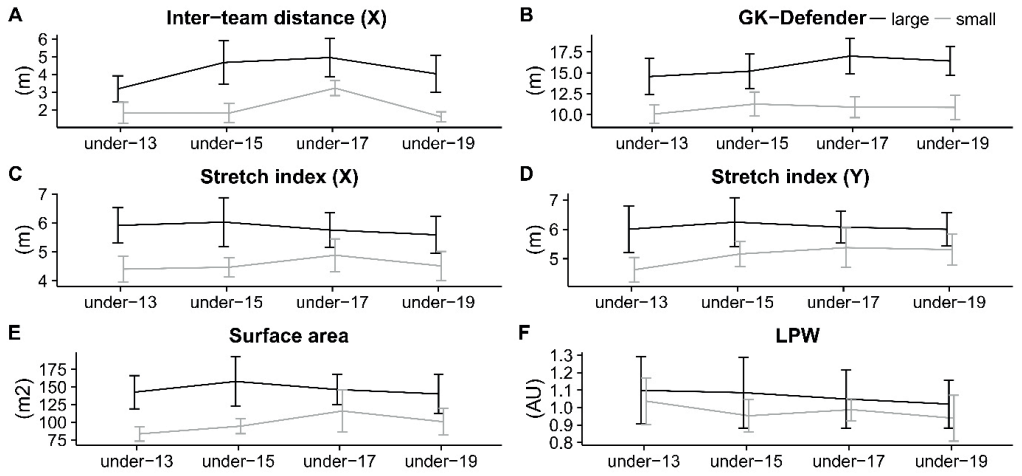

Figure 3.2. Team tactical performance measures (mean ± standard deviation) in SSGs played on a large and a small pitch in four age categories.

A significant main effect of pitch size was also found in tactical variability (F=25.49; p<.01). Tactical variability was significantly larger on a small pitch for inter-team distance (F=14.13; p<.01; η_p^2=.08), but larger on a large pitch for LPW-ratio (F=22.58; p<.01; η_p^2=.13), longitudinal (F=44.39; p<.01; η_p^2=.21) and lateral stretch index (F=28.03; p<.01; η_p^2=.14), surface area (F=7.65; p<.01; η_p^2=.04) and GK-defender distance (F=4.61; p<.05; η_p^2=.03, figure 3.3).

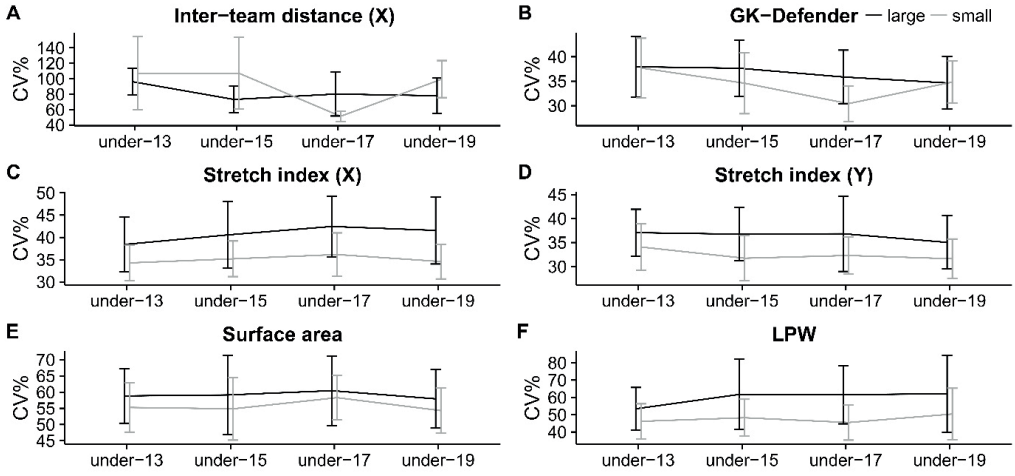

Figure 3.3. Variability of team tactical performance measures (mean ± standard deviation) in SSGs played on a large and a small pitch in four age categories.

Discussion

In the present study, the aim was to investigate soccer performance in SSGs played on a traditional small pitch size and on a large pitch size derived from the full-sized match. As they are often used in training sessions both to prepare for the full-sized match and to improve soccer skills, it is important to play representative SSGs (Araújo & Davids, 2015). The large pitch is a much larger manipulation than used in previous studies, as it has a relative pitch area derived from the full-sized match. As a consequence, main results were in accordance with the hypotheses: players covered more distance in total and in high speed zones and inter-team and intra-team distances were larger on the large pitch. Additionally, large pitch size evoked longer periods of ball possession and less transitions and more tactical variability of intra-team distance measures.

The current study confirmed the hypothesis that physical performance was significantly larger on a large pitch, emphasized by moderate to large effect sizes. These results are in accordance with previous studies where larger pitches evoked higher physical demands and no occurrence of sprints or HID on a small pitch (Casamichana & Castellano, 2010; Hodgson et al., 2014). Moreover, this study adds to the knowledge on physical performance on a match-derived relative pitch area by Castellano et al. (2015). 4 vs. 4 plus goalkeepers on a match-derived relative pitch area evoked similar high physical loads as games with a larger number of players and a similar higher

physical load than SSGs played on traditional small pitch sizes. This match-derived relative pitch area is a training format with the potential to be used as a representative learning environment for all number of players in a team (Araújo & Davids, 2015). A SSG played on pitch size with 320m^2 relative pitch area possibly affords physical demands similar to full-sized match demands, although current results on distance covered are higher (on average 130 m/s) than in the full-sized match of under-13 – under-15 New Zealand soccer players (on average less than 100 m/s) (Atan et al., 2016). However, full comparison to full-sized match performance is limited, because of the use of different speed thresholds or correction for differences in time duration.

Team tactical performance responded, as hypothesized, to the pitch size manipulation: a large pitch afforded larger inter-team and intra-team distances than a small pitch. Under influence of the match-derived relative pitch area, the space management of the teams altered with more distance between teams and a larger dispersion of the players within a team. Current results were in accordance with previous studies when playing on small pitch sizes. Longitudinal inter-team distance was similar to Frencken et al. (2013) and Olthof et al. (2015) (both on average 2m), but 1m smaller than Folgado et al. (2014). Longitudinal and lateral stretch indices and LPW-ratio were in accordance with results of Olthof et al. (2015) and Folgado et al. (2014). As expected, all inter-team and intra-team distances increased significantly when teams played on a match-derived pitch area. Players adopted a larger dispersion on the pitch, with larger interpersonal distances of the outfield players and larger distance between the goalkeeper and defenders. Evidently, small pitch sizes limited interpersonal distances, while match-derived relative pitch area afforded teams to adopt a larger dispersion both in the longitudinal and lateral direction.

Along with the increase of inter- and intra-team distances as a response to an increased pitch size, variability of the team tactical performance measures changed. Teams' self-organizing behaviour leads to continuously changing inter-team and intra-team distances (McGarry et al., 2002). Teams showed a more stable behaviour in inter-team distance on a large pitch, with less variability. A match-derived relative pitch area afforded significantly more tactical variability in intra-team distances than a small pitch. This likely corresponds with attacking behaviour where teams increase interpersonal distance to explore attacking opportunities and with defending behaviour where teams try to tighten interpersonal distance as much as possible to give the opponent no space for attacking exploration. Current research demonstrated that intra-team distances on a small pitch were smaller with less variability. Then, teams are in a compact organization constrained by the pitch size which does not allow much variability. On a large pitch, in contrast, teams can increase their intra-team distances in order to attack without being limited by pitch dimensions, but still

have the opportunity to decrease interpersonal distances to defend. This seems to be supported by the results of the game characteristics. Longer periods of ball possession on the large pitch gave teams more time to organize according to attack and defence, i.e. increase and decrease team size.

Pitch size manipulation affected game characteristics, displayed by differences in ball possession duration, number of transitions and goal attempts. Team dispersion and inter-team distance increased on a large pitch and it is likely that teams kept ball possession, because of larger interpersonal distances and less pressure of the opponent. Longer ball possession duration on a large pitch did not result in more goals or shots, which is in line with Lago & Martín (2007). They revealed that more ball possession was even negatively related to success. In SSGs on a large pitch, a player is less afforded to attempt a shot at goal, because distance to the goal is larger. This behaviour is more in line with the build-up of an attack in a full-sized match where the ball is passed around in order to try to score a goal.

Significant interaction effects demonstrate that differences in physical performance and team tactical performance between pitch sizes is amplified by age, but effect sizes were small. Players especially showed an increase in the high demanding HID and sprinting on a large pitch with older age. This is likely associated with an increase in inter-team distance and goalkeeper-defender distance on a large pitch as the age increased. On a small pitch with a high density of players, teams were forced to stand close to each other, but these interpersonal distances increased on a large pitch. Young players are inclined to play close to the ball, but did not show the same amount of increase in their interpersonal distances on a large pitch. This is likely to be explained because of their less developed physical and perceptual skills which hinders them from exploring the options they are afforded on the large pitch (Buchheit et al., 2010; Goto et al., 2015; Williams, 2000). Because speed thresholds are kept similar in this study, development of physical performance over age are emphasized on a large pitch. Dispersion measures as lateral stretch index and surface area increased on a small pitch with older age, which is in accordance with findings of Barnabé et al. (2016) and Olthof et al. (2015), but remained similar on a large pitch.

Results of this study provide soccer trainers insight in the effects of pitch size manipulations, where a larger pitch led to an increase in physical performance, inter-team and intra-team distances and ball possession duration. Findings of the effects of a match-derived relative pitch area in SSGs give trainers opportunities to design appropriate training formats that are more representative for the full-sized match, although future research is warranted to address this issue. Players perform in such SSGs in a similar relative playing area as in the 11-a-side game with similar performance outcomes. This playing area provides players time and space for exploration and

coordination similar to the full-sized match. This gives teams the opportunity in attack to increase their surface area and tighten interpersonal distances in defence.

Conclusions

The current study is the first investigating physical and team tactical performance together on a match-derived relative pitch area in four age categories across three youth academies of Dutch professional soccer clubs. Match-derived pitch area in 4 vs. 4 plus goalkeepers showed a major influence on all performance measures investigated in this study. Pitch size shaped physical performance, team tactical performance and game characteristics. Match-derived pitch area afforded soccer players more space to explore during attack and defence. This manipulation led to higher physical demands and allowed teams to increase intra-team distance resulting in larger surface areas and stretch indices and more tactical variability. Although the representativeness for the full-sized match needs to be established in future research, a match-derived relative pitch area has the potential to act as an adequate sampling of the match performance environment, which is important to create a representative learning environment for the player (Araújo & Davids, 2015). This enhances representativeness of SSGs for the full-sized match.

Disclosure statement

The authors report no conflicts of interest.

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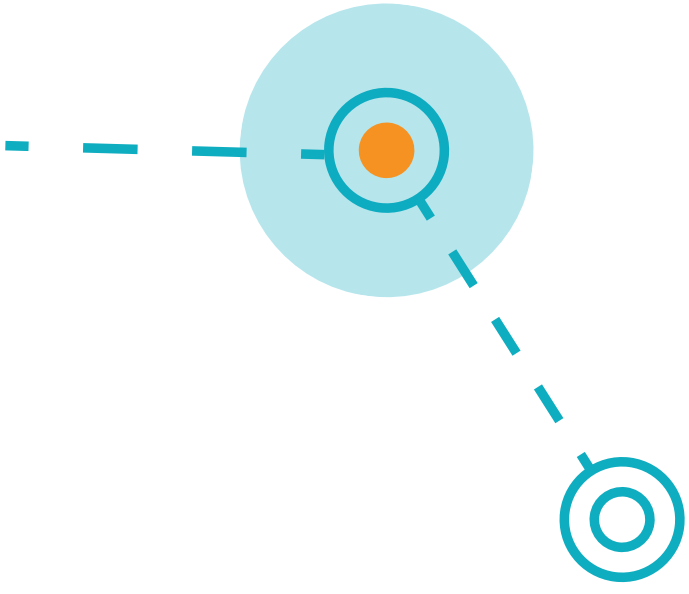

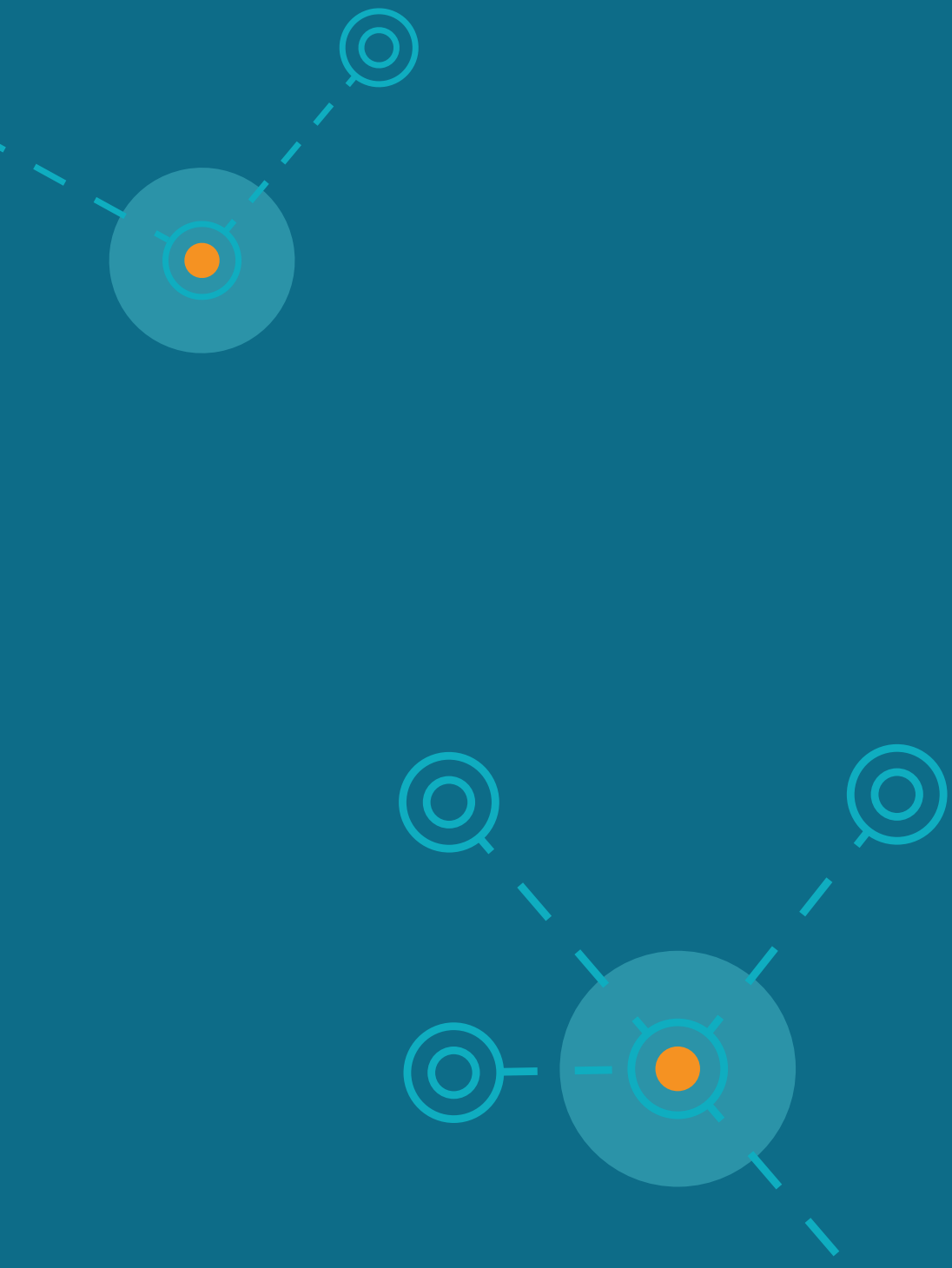

CHAPTER 4

A match-derived relative pitch area facilitates the tactical representativeness of small-sided games for the official soccer match

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Abstract

Small-sided games (SSGs) are a promising training format in soccer to replicate (situations of) the official match across all age groups. Typically, SSGs are played on a smaller relative pitch area (RPA; i.e. <150 m^2) than the match (320 m^2 RPA), which results in different tactical demands. To create a more precise replication of tactical match demands in SSGs with less than 11 players per team, a match-derived RPA (320 m^2) may be considered, because this affords a similar playing area per player. In addition, subgroup analysis is necessary to deal with the different number of players in match and SSGs. Therefore, this study aims to investigate tactical demands of matches and various SSGs – with a different number of players and played on 320 m^2 RPA – in talented youth soccer players. Twelve elite soccer teams in 4 age categories (under-13, under-15, under-17, and under-19) played official matches and 4 vs. 4 + goalkeepers (GKs), 6 vs. 6 + GKs and 8 vs. 8 + GKs. Positional data were collected to calculate tactical variables (interpersonal distances, length, width and surface areas) for all players and for 2- and 4-player subgroups. Corresponding tactical variability (coefficients of variation expressed as percentages) was determined for all players. Results demonstrated that in each age category, with an increase in number of players, team distances increased and tactical variability decreased. Subgroups analyses revealed similar team distances in matches and SSGs with the exception of larger interpersonal distances in 4 vs. 4+GKs than the match in under-13, under-15 and under-17. Match-derived RPA in SSGs facilitates the tactical representativeness for the match. Soccer coaches can use such SSGs for an optimal tactical match preparation.

Key words: Competition; practice; behavior; performance; tactical stimulus

Introduction

Small-sided games (SSGs) are regularly used in training sessions to simulate (specific situations of) an official soccer match. SSGs can be defined as training games with adaptations in pitch size, number of players and playing rules (Rampinini, Impellizzeri, et al., 2007). During SSGs, players simultaneously develop physical, technical, and tactical skills. According to principles of a representative learning design (Araújo & Davids, 2015), SSGs are the learning environment and should closely replicate the match in order to transfer skills from the training to the performance environment. Like the match, players are required to put their physical, technical and tactical skills into play in order to cooperate with team members and score goals, compete with the opponent and prevent them from scoring and eventually win the game. However, it is known that outcomes in physical, technical, and tactical performance are dependent on manipulations in pitch size and number of players (Aguiar, Botelho, Lago-Peñas, Maçãs, & Sampaio, 2012; Hill-Haas, Dawson, Impellizzeri, & Coutts, 2011). Therefore, performance in SSGs might therefore differ from the official match if not corrected for these factors.

Previous research shows that the relative pitch area (RPA) of an SSG shapes the action possibilities of players. An RPA is the individual space per player on the pitch, calculated as the total pitch area divided by the number of players (Casamichana & Castellano, 2010; Castellano, Puente, Echeazarra, & Casamichana, 2015). As an indication, the RPA of an official match equals approximately 320 m^2, but many SSGs in training sessions are typically played on 150 m^2 RPA or smaller (Aguiar et al., 2012; Hill-Haas et al., 2011). In general, a small RPA results in different physical and technical performance, i.e. less distance covered, high intensity runs and sprints, and more interceptions, transitions, tackles, and shots (Castellano et al., 2015; Kelly & Drust, 2009; Olthof, Frencken, & Lemmink, 2018; Vilar, Duarte, Silva, Chow, & Davids, 2014). In more detail, players cover more distance in total and at higher intensities in SSGs played on an RPA similar to the match (i.e. 320 m^2) than played on small RPAs (e.g. 100 or 200 m^2), regardless of number of players (Castellano et al., 2015) or age (Olthof et al., 2018). Thus, if SSGs are played on a match-derived RPA, similar physical performance is achieved as the match (Castellano et al., 2015). Therefore, in order to meet the physical demands from the match in SSGs, it is important to apply a match-derived RPA. However, it is largely unknown how team tactical behavior and different age categories respond to the use of match-derived RPA in SSGs.

Small-sided games played on a match-derived RPA might be a promising training format to replicate also the tactical demands from the official match. A match-derived RPA affords players a similar playing space as the match where information can be picked up by the players from their environment (such as team members,

opponents, ball, and pitch) which allows a selection and variation of appropriate soccer-specific actions. According to the concept of a representative learning design, an adequate sampling of the performance context (e.g., the official match) facilitates a positive transfer of skills acquired in the training to the match (Araújo & Davids, 2015). In Olthof et al. (2018), we demonstrated an increase in inter-team and intra-team distances and more tactical variability on a match-derived RPA than on a typical small RPA of 120 m^2. However, this team tactical behavior is only determined for 5-a-side games and the relation with actual match behavior remains unknown. Team tactical behavior in many SSGs with a small RPA differs from the official match. Frencken, Lemmink, Delleman, & Visscher (2011) and Duarte et al. (2012) detected crossings of team centroids in SSGs prior to goals and goal scoring opportunities, but this behavior has not been found in matches (Bartlett, Button, Robins, Dutt-Mazumder, & Kennedy, 2012). In addition, smaller interpersonal distances have been detected in SSGs with small RPAs compared to matches, demonstrated by smaller stretch indices and larger length-per-width ratios in SSGs (Folgado, Lemmink, Frencken, & Sampaio, 2014; Olthof, Frencken, & Lemmink, 2015) than in matches (Frencken, Poel de, Visscher, & Lemmink, 2012; Olthof, Frencken, & Lemmink, 2019). Altogether, manipulations in both player number and pitch size in SSGs result in smaller distances between players and this seems a less appropriate design to replicate the demands of the match. In line with results for physical performance, a match-derived RPA in SSGs can be used to more precisely mimic the tactical demands, regardless of the number of players. However, these pitch manipulations depend on number of players, and team tactical variables typically increase after including more players (Aguiar, Gonçalves, Botelho, Lemmink, & Sampaio, 2015; Gonçalves et al., 2018; Silva, Vilar, Davids, Araújo, & Garganta, 2016). Therefore, research is warranted to determine team tactical behavior in SSGs with a match-derived RPA, to compare this with performance in official matches and to correct for a difference in number of players for a fair comparison. A suitable approach may be the use of subgroups (Gonçalves et al., 2018; Memmert, Lemmink, & Sampaio, 2017), where a unit of players is selected to allow a correction in team tactical variables for a different number of players and, as such, be able to compare SSGs with the match.

Besides the impact of adaptations in player number and pitch sizes, there is also a considerable influence of age on team tactical behavior. In general, with an increase in age, inter-team and intra-team distances increase in SSGs in elite and amateur soccer players aged under-13 to under-19 (Barnabé, Volossovitch, Duarte, Ferreira, & Davids, 2016; Folgado et al., 2014; Olthof et al., 2015). During 5-a-side games played on a pitch of 320 m^2 RPA, distance between teams and dispersion of players were larger in players aged under-13 to under-19 than on 150 m^2 RPA (Olthof et al., 2018). These studies have shown that age groups deal differently with the available

space, showing different positioning of players on the pitch. Therefore, the relation of SSGs with the official match might differ amongst age groups, but solid evidence for this lacks.

Taken together, RPAs in SSGs are typically much smaller than an official match. These manipulations augment specific technical or physical aspects of a soccer match. However, SSGs played with a match-derived RPA are promising in order to mimic the tactical aspects of the match as closely as possible. Therefore, the aim of this study was to determine the relation between soccer performance in SSGs played on an RPA of 320 m^2 with a different number of players (5 vs. 5, 7 vs. 7 and 9 vs. 9) and the official matches across 4 age categories (under-13, under-15, under-17, and under-19), measured by several team tactical variables. The hypothesis was that from playing SSGs on an RPA of 320 m^2, comparable tactical behavior will emerge as during the official match, if corrected for the number of players.

Methods

Experimental Approach to the Problem

Elite youth soccer teams played official matches and various small-sided games with a similar RPA of 320 m^2. A cross-sectional design is used to investigate inter-team and intra-team distances and tactical variability in competition and training. Positional data were collected with the Local Position Measurement system and video footage was recorded during the 2015-2016 Dutch competitive season. In addition, sub-group analyses are applied to deal with the difference in number of players in teams and to be able to compare tactical match demands with tactical SSG demands.

Subjects

For the purpose of this study, 12 soccer teams with a total of 280 elite youth soccer players from 3 Dutch professional youth academies participated. The teams represented 4 age groups: under-13 (n = 3 teams; 57 players; mean ± SD 12.7 ± 0.4 years; range 11.6 to 13.6 years), under-15 (n = 3 teams; 74 players; mean ± SD 14.2 ± 0.6 years; range 12.6 to 15.1 years), under-17 (n = 3 teams; 73 players; mean ± SD 16.3 ± 2.1 years; range 13.5 to 17.0 years) and under-19 (n = 3 teams; 76 players; mean ± SD 18.3 ± 2.5 years; range 16.0 to 21.4 years). Each team played official matches during Dutch national competition and most teams played multiple bouts of 4 vs. 4 + goalkeepers (GKs), 6 vs. 6 + GKs and 8 vs. 8 + GKs during training sessions. All players were notified of the purpose of the study. Players (and their parents or legal guardians if the player was younger than 18 years old) signed an informed consent. All procedures were approved by the

local ethical committee of the Center for Human Movement Sciences of the University Medical Center Groningen, University of Groningen, the Netherlands.

Procedures

Official matches were played during the competitive season and official playing rules were applied. A difference in play duration was present amongst age groups in accordance with official rules for the Dutch competition, i.e., 2 x 45 minutes in under-19, 2 x 40 minutes in under-17, 2 x 35 minutes in under-15, and 2 x 30 minutes in under-13. Matches were played on artificial turf pitch of 105 x 68 m. Teams were allowed to play according to their club's strategy and there was no researcher's involvement in starting formation and substitutions. All teams played, however, in a 1-4-3-3 playing formation.

Pitch sizes in the SSGs were designed based on a similar RPA, i.e., 320 m^2, and a similar ratio between pitch length and width as the official match. That results in a 68 x 47 m pitch for 4 vs. 4 + GKs, a 80 x 56 m pitch for 6 vs. 6 + GKs, and a 91x63m pitch for 8 vs. 8 + GKs. A different number of repetitions, playing duration, and starting line-up per SSG was chosen based on the opinion of expert coaches. Four vs. 4 + GKs was played for 5 x 4 minutes (1-2-1-1 playing formation), 6 vs. 6 + GKs was played for 5 x 5 minutes (1-2-3-1 playing formation) and 8 vs. 8 + GKs was played for 3 x 10 minutes (1-3-3-2 formation). To ensure optimal recovery for the subsequent SSG, there was a 4-minute rest period in between the games (Köklü, Alemdaroğlu, Dellal, & Wong, 2015). Official FIFA-approved goals (7.32 x 2.44 m) were used and the penalty box was proportionally reduced. Small-sided games were played on artificial turf pitch.

The coach divided the players over the teams to equally balance the quality of the teams. Coaches were allowed to substitute between SSGs to create randomness or in case of an injury during the SSG. They were instructed to coach in a similar way as during the official match. Official playing rules were applied in the SSGs and the purpose of the SSGs was to win by scoring more goals than the opponent.

Data collection

Positional data were collected in all official matches and SSGs with the LPM System (Inmotio Object Tracking BV., Amsterdam, the Netherlands). This is a validated instrument to obtain objective and accurate x- and y-coordinates of all players on the pitch (W. G. P. Frencken, Lemmink, & Delleman, 2010; Ogris et al., 2012). Each player wore a vest with a transponder during the matches and training. Sampling frequency for data collection ranged 34 to 91 Hz. In addition, video footage was recorded with high-definition dome cameras and high-resolution digital cameras. Videos were synchronized with positional data in the Inmotio software. Start and end of the SSGs

and matches were marked based on audio-visual inspection of the videos.

Data processing

Performance measures in the remainder of the analyses were corrected for effective playing time. Stoppages of play were removed from the total duration of the SSG or match (Aguiar, Gonçalves, Botelho, Duarte, & Sampaio, 2017; Silva, Chung, et al., 2016). Stoppages were determined with video analysis when the ball is out of play or the game is stopped because of a goal, injury or substitution. After the stoppage, the game resumed with a set piece (throw in, corner kick, goalkeeper kick, free kick or kick-off). The remaining time was considered as effective play time (Olthof et al., 2019).

Each pass was counted with notational analysis. Total number of passes were corrected for number of players in the team and effective playing time and displayed as passes per minute per player. Notational analysis was performed by multiple raters using Noldus The Observer XT (Noldus Information Technology, Wageningen, the Netherlands). A study on an unpublished dataset was used to assess systematic observation between multiple raters. This revealed an inter-reliability agreement of 0.79 (Cohen's *k*).

Positional data was used to calculate several tactical variables for each point in time in Matlab R2015b (The Mathworks, Inc., Natick, MA, USA). Interpersonal distance is the average radial distance (m) between a player and his team members (Vilar, Araújo, et al., 2014; Vilar, Duarte, et al., 2014). The maximum distance between players in either longitudinal or lateral direction is the team length and width (m), respectively. Team's surface area is the area bounded by the convex hull (m^2) (W. Frencken et al., 2011). Tactical variability was determined for team length, width, and surface area with coefficients of variation and expressed as percentages (Gregson, Drust, Atkinson, & Di Salvo, 2010; Rampinini, Coutts, Castagna, Sassi, & Impellizzeri, 2007). Tactical variability represents the change of these tactical variables over time during a match or SSG.

Subgroups were determined to correct tactical variables for differences in number of players (Memmert et al., 2017). For each player at each point in time, the nearest team member was determined (Gonçalves et al., 2018). Subgroups were considered for units of 2 or 4 nearest team members. These subgroups are respectively the smallest and largest groups possible to compare SSGs with the official match. Then, the team tactical variables were calculated for the subgroups, with exception of the surface area for the subgroup of 2 players.

Statistical Analyses

Data were checked on quality and normal distribution. Positional data quality of 6 players in 1 match and 3 SSGs were poor. Therefore, the corresponding team tactical measures were excluded for further analysis. Then, means and *SD*s were calculated for each team in Matlab R2015b.

A customized R routine was used for further statistical analyses (R for Windows 324; R Foundation for Statistical Computing, Vienna, Austria). A mixed-model approach was used to test for differences in the dependent variables (pass characteristics, tactical variables, and tactical variability) among age groups (fixed factor) and between SSGs and official matches (random factor) using the nlme package (Pinheiro, Bates, DebRoy, Sarkar, & R Core Team, 2017). Planned pairwise contrasts using the MASS package (Venables & Ripley, 2002) were applied to test each SSG against the match for all age groups and within each age group. Differences among age groups were tested with pairwise contrasts between under-19 and younger age groups for match performance. Significance was set at $p < 0.05$. Effect sizes were calculated using Pearson's R (r) (Rosnow, Rosenthal, & Rubin, 2000) and were considered as small ($r < 0.30$), moderate ($0.30 \leq r < 0.50$) or large ($r \geq 0.50$). Confidence intervals (CIs) of 95% were provided for differences between match and training game. Given the number of contrasts, (the range of) p-values, effect sizes, and confidence intervals were presented in case of significant results.

Results

Table 4.1 displays the sample of SSGs and matches, effective playing time and passes per player per minute. Not all teams played each SSG format. Compared to the match, there were significantly more passes per minute played during 4 vs. 4 + GKs ($0.30 < r < 0.48$; $0.4 < CI < 2.1$) and 6 vs. 6 + GKs ($0.24 < r < 0.30$; $0.2 < CI < 2.0$) across all age groups and during 8 vs. 8 + GKs in under-19 ($r = 0.18$, CI 0.0 : 1.1).

Table 4.1. Number of SSGs and matches played, mean ± SD of effective play time and passes/min in all age categories*†.

		under-13	under-15	under-17	under-19
N	4 vs. 4 + GKs	10	15	10	10
	6 vs. 6 + GKs	5	15	10	11
	8 vs. 8 + GKs	3	9	3	6
	Match	5	6	6	4
Effective playing time (%)	4 vs. 4 + GKs	85.1 ± 9.68	80.1 ± 5.98	81.9 ± 4.58	86.8 ± 6.16
	6 vs. 6 + GKs	90.2 ± 1.32	79.3 ± 7.95	85.2 ± 6.23	83.9 ± 6.94
	8 vs. 8 + GKs	80.8 ± 1.45	84.8 ± 5.78	77.9 ± 9.18	91.3 ± 5.11
	Match	69.7 ± 5.55	67.6 ± 9.15	66.3 ± 7.27	69.5 ± 5.41
Passes/min	4 vs. 4 + GKs	1.9 ± 0.44§	1.9 ± 0.65§	2.3 ± 0.60§	2.4 ± 0.50§
	6 vs. 6 + GKs	2.0 ± 1.45§	1.7 ± 0.32‡	1.7 ± 0.54§	1.7 ± 0.49‡
	8 vs. 8 + GKs	1.0 ± 0.15	1.4 ± 0.65	1.3 ± 0.21	1.4 ± 0.17‡
	Match	0.7 ± 0.13	0.9 ± 0.19	0.7 ± 0.19	0.8 ± 0.26

*SSGs = small-sided games; GKs = goalkeepers.

† Number of SSGs and matches and effective playing time were not statistically evaluated.

‡ Significantly different from match within age category ($p < 0.05$).

§ Significantly different from match within age category ($p < 0.001$).

All players

Team's tactical variables for all players are presented in figure 4.1. Pairwise contrasts revealed that interpersonal distance, surface area, and team's length and width were significantly smaller in all SSGs than the match across all age categories ($p < 0.001$; -25.4 < CI -1.0 for interpersonal distance, length and width; -931.4 < CI < -265.1 for surface area). Effect sizes revealed large effects for 4 vs. 4 + GKs ($0.76 < r < 0.96$) and 6 vs. 6 + GKs ($0.54 < r < 0.93$) and moderate to large effects for 8 vs. 8 + GKs ($0.31 < r < 0.81$). In addition, under-13 showed a significantly smaller surface area in the match than under-19 ($p < 0.05$; $r = 0.22$; CI -138.8 : -14.9; figure 4.1D). Variability of the team tactical variables is presented in figure 4.2. In each age group and for team length, width, and surface area, there was significantly more variability detected in the 4 vs. 4 + GKs than in the official match ($0.45 < r < 0.67$; 8.2 < CI < 34.5). Also significantly more variability was detected in 6 vs. 6 + GKs ($0.18 < r < 0.40$; 0.2 < CI < 20.2) and 8 vs. 8 + GKs ($0.14 < r < 0.26$; 0.5 < CI < 12.0) in tactical variables, but not in each age group.

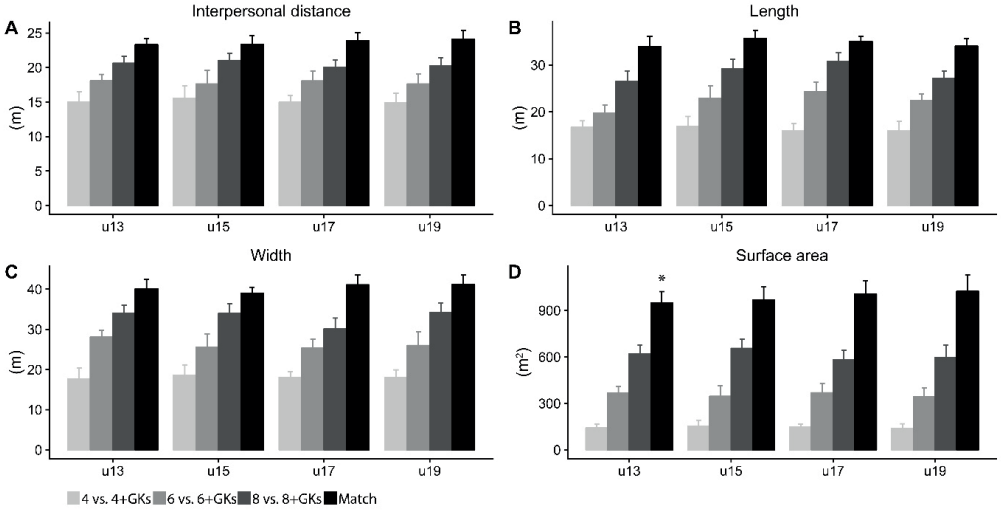

Figure 4.1. Tactical variables determined for all players in the team for (A) interpersonal distance, (B) team length, (C) team width, and (D) team surface area across 4 age categories. All SSGs show significant smaller values than the match within an age category (p < 0.001). Significantly different from under-19 match (* p < 0.05). SSGs = small-sided games; GKs = goalkeepers.

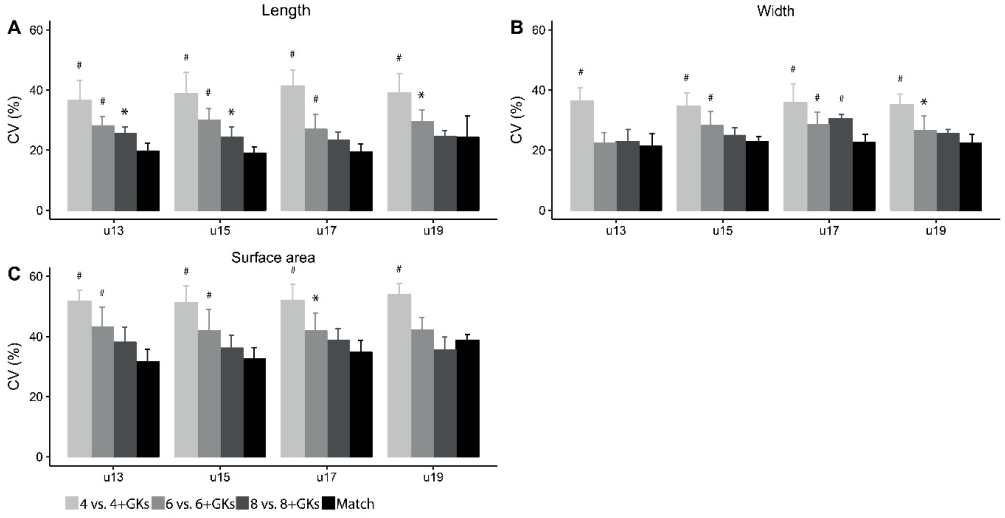

Figure 4.2. Tactical variability displayed by coefficients of variation (CV) for (A) team length, (B) team width, and (C) team surface area across 4 age categories. Significantly different from match within age category (*p < 0.05 and $^{\#}p$ < 0.001). GKs = goalkeepers.

Subgroup of two players

Figure 4.3 presents the tactical variables of the smallest subgroup. With the exception of a significantly smaller width in under-19 during 6 vs. 6 + GKs than the match (r = 0.18; CI -1.3 : 0.0; figure 4.3C), there were no differences in the interpersonal distance, length, and width between the SSGs and the official match in all age groups.

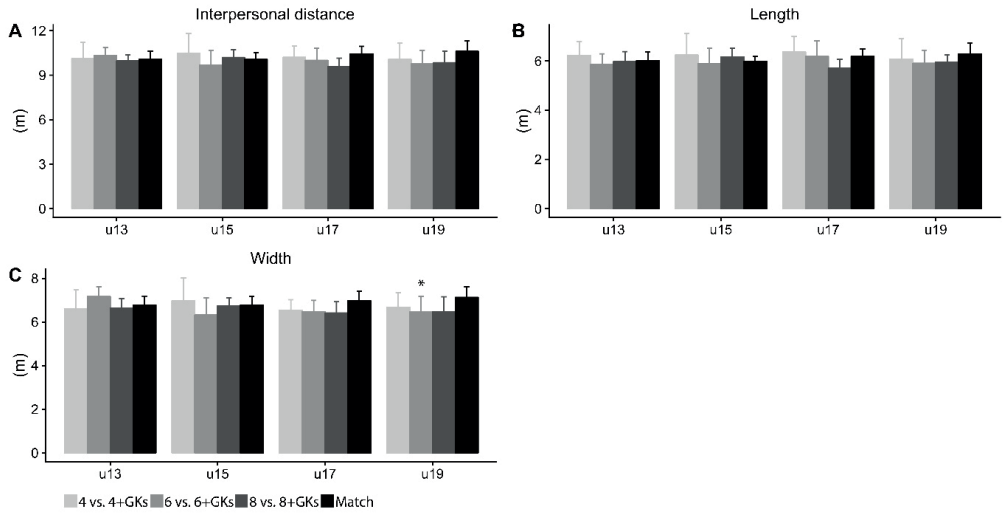

Figure 4.3. Tactical variables determined for subgroups of 2 players for (A) interpersonal distance, (B) length, and (C) width across 4 age categories. Significantly different from match within age category (* p < 0.05). GKs = goalkeepers.

Subgroup of four players

In figure 4.4, tactical variables for subgroups of 4 players are presented. In the 3 youngest age groups, interpersonal distances during 4 vs. 4 + GKs were larger than the match (0.19 < r < 0.35; 0.1 < CI < 3.1; figure 4.4A). A larger average width was present in under-15 during 4 vs. 4 + GKs than the match (r = 0.21; CI 0.3 : 3.3; figure 4.4C). In under-19, surface area was smaller during 6 vs. 6 + GKs (r = 0.22; CI -47.1 : -5.1) and 8 vs. 8 + GKs (r = 20; CI -50.3 : -3.9; figure 4.4D) and length was smaller during 8 vs. 8 + GKs (r = 0.18; CI -3.1 : -.1; figure 4.4B) than the match.

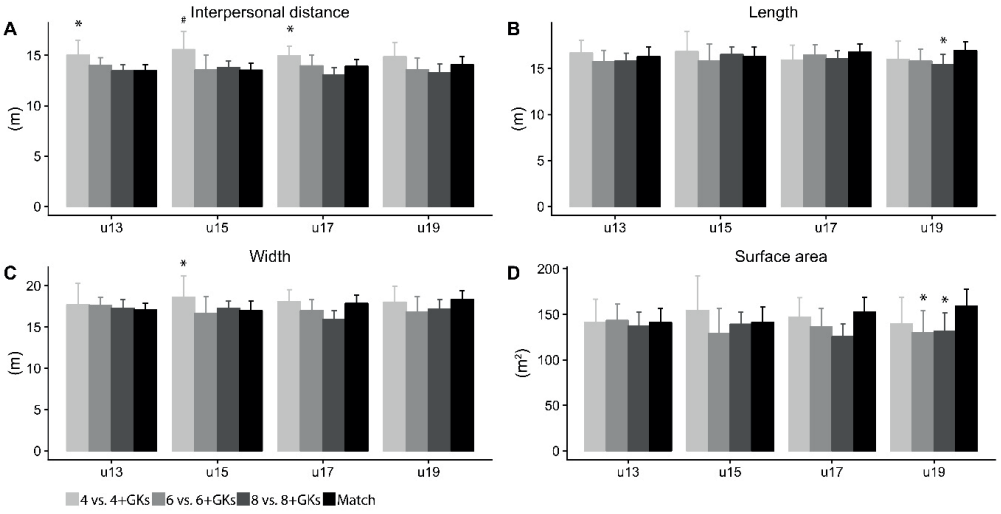

Figure 4.4. Tactical variables determined for subgroups of 4 players for (A) interpersonal distance, (B) length, (C) width, and (D) surface area across 4 age categories. Significantly different from match within age category (* $p < 0.05$ and # $p < 0.001$). GKs = goalkeepers.

Discussion

This study aimed to compare team tactical behavior in the official match with various SSGs, in which number of players varied (formats) and the relative pitch area was kept constant (320 m^2 per player). To meet this purpose, an analysis with all players in the teams was conducted along with 2 analyses with subgroups to correct for the difference in number of players. Main findings of this study were that with an increasing number of players, values of team tactical variables increased and values of tactical variability decreased simultaneously. In addition, 2-player and 4-player subgroup analyses showed that interpersonal distances, length, width, and surface area were in general similar between SSGs and the official match across age groups. Differences were detected with 4-player subgroup analysis, which revealed larger interpersonal distances in the smallest SSG than the match in the age groups under-13, under-15 and under-17 and smaller length and surface area in the 2 largest SSGs for under-19.

Values for team tactical variables increased with more players in a team. This finding is in line with previous observations for subgroups in a match (Gonçalves et al., 2018) and for different formats of SSGs up to 5 players in a team (Aguiar et al., 2015; Silva, Vilar, et al., 2016). Results of the current study add that this increase also takes place in SSGs with more players in a team, i.e., 6 vs. 6 + GKs and 8 vs. 8 + GKs. Players tend to organize and choose position based on information picked up from the

performance environment: position of team members, opponents, the ball, and the available space (Araújo, Davids, & Hristovski, 2006; Davids, Araújo, Hristovski, Passos, & Chow, 2012). Logically, a consequence is that the distance between players increases when there are more players in a team to keep a well-structured team organization. To illustrate, team length increased to deal with the additional players in between them, resulting in a larger defender-attacker distance. In addition, tactical variability showed opposite results with an increase in variability for team tactical variables with less players in a team. This indicates that smaller teams were more inclined to change their dispersion. Less variability detected in larger-sized teams indicates that these teams were less sensitive for changes in their team dispersion, and likely, players stick more to their position in a team formation. Teams adjust their dispersion in accordance with a changing number of players in order to maintain team organization when more players participate in the SSG, as suggested by Silva, et al. (2016).

Next to the analysis of all players in the team, subgroups of 2 players give the opportunity to compare tactical variables of SSGs with matches and to investigate the structure within team dispersion measures. Although under-19 showed a smaller width during 6 vs. 6 + GKs than the match, which displays a smaller lateral distance between 2 nearest players in this game format, this subgroup showed similarities in all other tactical variables for SSGs and official matches. This indicates that players maintained a similar position in reference to their nearest player. This behavior is likely facilitated by the playing area in the SSGs. As their individual area was similar to the match on average, players had sufficient space to maintain a preferred distance. Yet, in contrast to small RPAs, they were not constrained by a small playing area which forces players to play closer to their team members (Frencken, Plaats van der, Visscher, & Lemmink, 2013; Olthof et al., 2018). Analysis of subgroups of 2 players and playing SSGs on a 320 m^2 RPA revealed that players were able to maintain a similar distance to their nearest team member and, in that way, keep a structured team organization, regardless of the number of players in a team.

A subgroup of 4 players was the largest unit possible to compare in the current study and displayed the dispersion of players within a subunit. This revealed differences between SSGs and matches. Larger interpersonal distances had been found during 4 vs. 4 + GKs than during the match in under-13, under-15 and under-17. In an SSG with 4 outfield players, individual players are more frequently involved with the ball than in the match, which is displayed by a higher number of passes per player per minute (table 4.1). In addition, players may pick up different information from their environment because there are less players in a team and they play on a relatively large pitch (Araújo et al., 2006), meaning less restrictions to choose position in reference to the players around them and the markings of the pitch. The combination of a relatively

small number of players and large pitch caused a larger tactical variability, more individual ball involvement, and larger dispersion of players in the subgroup. In this study, under-19 is an exception to this finding because a smaller length and surface area have been detected during 6 vs. 6 + GKs and 8 vs. 8 + GKs in comparison to the match. A possible explanation is that, due to more years of soccer experience, this age group tried to maintain a playing formation with 3 functional lines, without having a full pitch length to use. Possibly, this made it more difficult to maintain a preferred distance between lines which resulted in smaller length and surface area. In sum, analysis of a subgroup of 4 players showed differences in distances between players in 4 vs. 4 + GKs, but revealed similarities between SSGs and official matches. Within a subunit of 4 players, players maintained a similar distance to each other during SSGs on a match-derived RPA compared to the match.

To conclude, team dispersion increased with more players in a team, displayed by an increase in team length, width and surface area, and interpersonal distances. Simultaneously, passes per player decreased with more players on the pitch. Further analysis of subgroups revealed similar length, width, and interpersonal distance between 2 nearest team members during SSGs and the match, but larger interpersonal distances during 4 vs. 4 + GKs in the youngest age groups when subgroups of 4 players were analyzed. Subgroup analyses give greater understanding of the structure within a team and allow comparisons of tactical behavior between the official match and SSGs. The increase of team dispersion measures in all players is functional to deal with the players on the pitch,ticular when a larger number of players are used.

Practical applications

Altogether, current results give rise to practical implications for daily soccer practice and promote applications for team tactical training. Previous studies revealed that playing SSGs on an RPA of 320 m^2 are useful to replicate the physical demands of the official match (Castellano et al., 2015) and affords tactical variability useful for attacking exploration and defending organization (Olthof et al., 2018). Results from current study add to this knowledge that such SSGs also replicate tactical behavior from the match, such as similar distances between players and dispersion within subgroups. An RPA of 320 m^2 will promote similar interpersonal distances as the match in contrast to SSGs with smaller RPAs. From a match-derived RPA, soccer-specific behavior emerges: similar distances between players to pass the ball and sufficient space available to run and become available to receive a pass. This enhances tactical representation of SSGs for the match for a smaller number of players and can be used by soccer trainers who aim to prepare for the official match. Moreover, the off-side rule can be applied,

which promotes the similarities of behavior between SSGs and the match. However, soccer coaches should be aware of the increase in pass involvements per player with a lower number of players, which, in turn, augments a technical stimulus to players. In addition, this format is also a very suitable SSG design for nonstarting players or substitutes who lack tactical stimulus from the official match.

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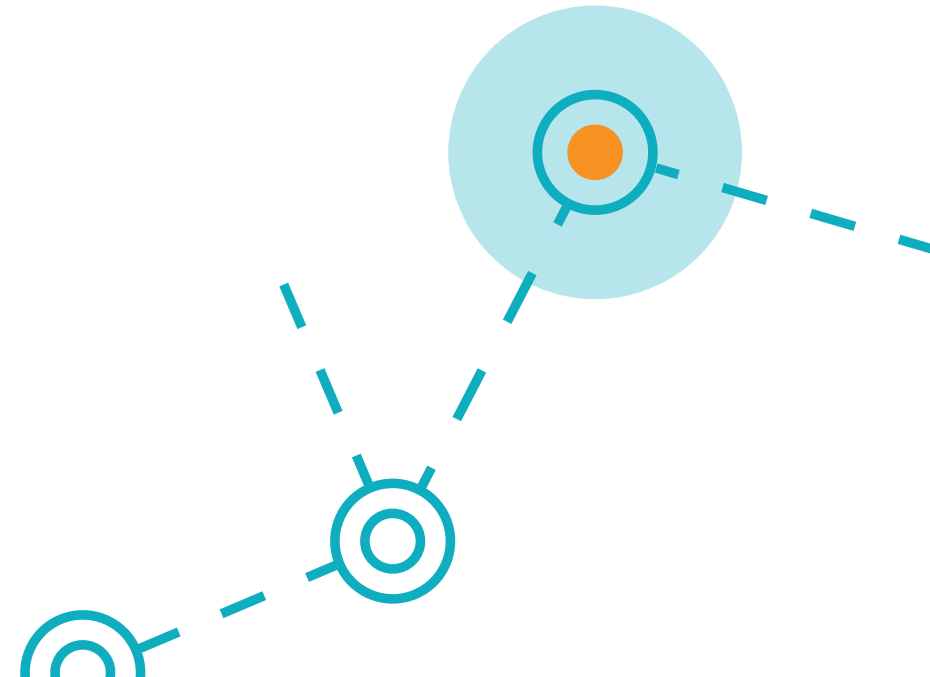

CHAPTER 5

When something is at stake: differences in soccer performance in 11 vs. 11 during official matches and training games

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Abstract

11 vs. 11 training games are used to mimic the official match, but differ in playing duration and a consequence of winning or losing. Anxiety levels, crowd pressure and the intention to win are examples of constraints present in the match, but absent or less prevalent in training. The aim is, therefore, to compare soccer performance in official matches with 11 vs. 11 training games. Six elite youth soccer teams played 5 official matches and 15 training games. Soccer performance, defined as a combination of game characteristics (game duration, transitions and ball possession duration) and physical (distance covered, high intensity distance and sprints), technical (passing), and team tactical performance (inter-team and intra-team distances) and corresponding interaction patterns, was determined with video footage and positional data (LPM-system). Soccer performance in official matches differed from similar training games, in a way that players covered more distance, sprinted more often, but game pace was lower and players made more mistakes. In addition, team width was smaller and LPW-ratio larger and teams were tighter coupled in official matches. 11 vs. 11 training games can be used to mimic the match, in particular the team tactical performance. Coaches could increase physical and technical representativeness of training games by raising the stakes and increase the consequence of winning or losing.

Key words: Full-sized match; coordination patterns; football; talent

Introduction

Two teams of eleven players, pitch size, and official playing rules shape the performance of players in an official soccer match (Grehaigne, Bouthier, & David, 1997). Soccer performance in the match is typically quantified in physical, technical, and team tactical performance measures. In particular, high intensity activities, various on-ball actions (such as passing) and inter-team and intra-team measures have been subject to research to investigate elite soccer performance (Abt & Lovell, 2009; Lago-Peñas & Martín, 2007; Memmert, Lemmink, & Sampaio, 2017). These performance measures give insight in the movement activities and coordination patterns of players and teams, which is helpful to quantify the match load and subsequently design training sessions. However, this information is still fragmented into subdisciplines of sport science, rather than that they provide a holistic view of soccer performance (Bradley et al., 2015; Glazier, 2017).

Training games during soccer practice are designed to simulate (situations from) the match and combine the physical, technical and tactical skills in an exercise (Hill-Haas, Dawson, Impellizzeri, & Coutts, 2011). In particular, the 11 vs. 11 training game is intended to closely mimic the match with similar playing rules, number of players, pitch size, and playing rules. Therefore, this training game meets the requirements of a representative learning design as suggested by Araújo & Davids (2015) and Davids, Araújo, Hristovski, Passos & Chow (2012), which would optimally enable a positive transfer of skills from training to performance environment (i.e. the official match). From the expert opinion of soccer trainers, 11 vs. 11 is regularly played in training sessions for an optimal tactical match preparation, rather than e.g., a physical training stimulus. This is strengthened by Djaoui, Chamari, Owen, & Dellal (2017), who revealed higher peak sprinting speeds in the official match than in an 11 vs. 11 training game. Even though match and training contexts look alike, these findings suggest that there may be differences in constraints underlying to these differences in performance outcomes.

In daily practice, soccer trainers often compromise in playing duration and choose to play training games with shorter duration and multiple bouts to control the physical stimulus (Aguiar, Botelho, Lago-Peñas, Maçãs, & Sampaio, 2012). It rarely happens that the 11 vs. 11 game is played for 90 minutes. Logically, this compromise stresses the physical capacities of the players differently in relation to the match. Moreover, a training game differs from the official match in attention of a crowd, a relative unknown opponent, and the pressure to win. These constraints can be categorized into environment and players, which consequently shape behavior (Glazier & Robins, 2013; Newell, 1986). From the consequence of winning or losing, a specific set of constraints evolves and this characterizes a high pressure in a match where 'something is at stake' (Oudejans & Nieuwenhuys, 2009). However, in order to enhance

learning, this pressure is often removed from training (Headrick, Renshaw, Davids, Pinder, & Araújo, 2015; Oudejans & Nieuwenhuys, 2009). Hypothetically, this different set of constraints influences physical, technical and team tactical performance (Glazier & Robins, 2013; Newell, 1986). However, both the effects of differences in task duration and match constraints have been understudied in previous research.

Altogether, this study aims to compare performance in the official match with an 11 vs. 11 training game and provide a holistic view of soccer performance. Physical and technical performance measures reflect individual performance of players, whereas team tactical performance measures reflect collective behavior, such as team's dispersion on the pitch and coordination patterns. Based on the principles of the representative learning design, 11 vs. 11 training games should closely simulate the official match conditions, but the soccer performance might be different because of different set of constraints. For daily practice, this research will provide insight to soccer trainers how an 11 vs. 11 training game relates to the actual match demands.

Methods

Experimental Approach to the Problem

Six teams representing three professional youth academies played official matches and 11 vs. 11 training games to evaluate soccer performance during competition and practice. A cross-sectional design is used to test the differences in typical physical, technical, and team tactical performance measures and corresponding interaction patterns (Abt & Lovell, 2009; Bourbousson, Sève, & McGarry, 2010; Folgado, Lemmink, Frencken, & Sampaio, 2014; Frencken, Van Der Plaats, Visscher, & Lemmink, 2013) between official matches and training games. Data were collected with a Local Position Measurement (LPM) system and video footage during the 2015-2016 Dutch competitive season. An integration of the performance measures provides a holistic view of the soccer performance during match and practice.

Subjects

Six teams of three Dutch youth academies of professional soccer teams participated in this study. These teams were assigned to two age groups, under-17 (n = 70 players; 16.1 ± 1.38 years; range 14.9-17.1 years) and under-19 (n = 73 players; 18.1 ± 1.16 years; range 16.6-25.8 years), and played official matches and 11-a-side training games. All players were informed about the purpose of the study and each player (and parents/legal guardians if the player was younger than 18 years) gave written informed consent. All procedures were approved by the local ethical committee of Human Movement

Sciences of the Medical Faculty of the University Medical Center Groningen, University of Groningen, the Netherlands.

Procedures

Each official match was played according to the official playing rules and duration. For the duration, this implies that under-19 played 2 x 45 minutes and under-17 2 x 40 minutes. In total, 5 official matches were played: 2 in the under-19 age group and 3 in the under-17 age group. There was one external opponent in the under-17 match, the other matches were between the participating youth academies. All official matches were played as part of the under-17 and under-19 competition at national level.

Per team, three 11-a-side games were played in the training session. Each game was played for 10 minutes with a 4-minute rest period in between the games to ensure optimal recovery for the subsequent game (Köklü, Alemdaroğlu, Dellal, & Wong, 2015). The 11-a-side games were preceded by a warm-up containing exercises with and without the ball. In total, 6 training games were played in the under-17 age group and 9 training games in the under-19 age group. Official playing rules were applied in these games. Coaches were instructed to coach in an activating and encouraging style, just like they would do in a competitive match (Rampinini et al., 2007). In-game substitutions only took place in case of an injury.

Team formation was similar in the official matches and the 11-a-side games. All teams played in a 1-4-3-3 formation and teams were allowed to play according to their club's playing style in both match and training game. Each match and game was played on an artificial turf pitch with pitch dimensions of 105 x 68 m.

Data collection

During the official matches and 11-a-side games, positional data was collected from each player with the LPM system (Inmotio Object Tracking BV., Amsterdam, the Netherlands). Each player wore an LPM-vest to collect individual x- and y- coordinates. This data collection took place with a sampling frequency ranged 34-45 Hz, depending on the total number of players (starting formation and substitutes) assigned in the data collection (Frencken, Lemmink, & Delleman, 2010; Ogris et al., 2012).

In addition, video footage was recorded with 1 or 2 HD dome cameras (Bosch GmbH., Stuttgart, Germany) and 1 or 2 high resolution digital cameras (available from university and youth academies) to ensure that all 22 players on the pitch were visible. Videos were automatically synchronized with the positional data in the Inmotio software.

Data analysis

Calculations were performed in the data analysis using customized Matlab routines (Matlab R2015b, The Mathworks, Inc., Natick, MA, USA).

Game Characteristics. Total game duration was the duration between start and end of each match and game, any injury time included. Stoppages of play were excluded (Aguiar, Gonçalves, Botelho, Duarte, & Sampaio, 2017; Silva et al., 2016) and the remaining time was considered as effective playing time. The ball was out of play or the game was stopped for an injury, substitution or after a goal was scored. The game resumed after set pieces (throw in, corner kick, goalkeeper kick, free kick or kick-off) when the player involved was ready and had the intention to resume the game. Relative playing time was calculated as the percentage effective playing time of the total game duration.

Ball possession of each team was analyzed with video analysis. Ball possession duration was determined when a team was in control of the ball until the moment the ball was out of play or the opponent won ball possession by an interception or duel (Aguiar et al., 2017; Collet, 2013). A transition was defined as a change in ball possession from one team to the other. Transitions were expressed as the number of transitions per minute of effective playing time to normalize for the difference in total game duration and effective playing time.

Physical Performance. Total distance covered, high-intensity distance (HID) and number of sprints were calculated with the positional data. Because the match and training games had different durations and effective playing times, physical performance variables were determined for the effective playing time. Total distance covered was expressed as meters per minute, HID as the percentage of the total distance covered by a player above 19.8 $km \cdot h^{-1}$ and the number of sprints as the frequency ≥25.2 $km \cdot h^{-1}$ per minute (Abt & Lovell, 2009).

Technical Performance. Each pass was counted and evaluated on direction and success with notational analysis. Total number of passes of the team was corrected for the effective playing time and represented the pace of the game. The number of incorrect passes and forward passes were expressed as the percentage of total passes.

Team Tactical Performance. Positional data were used to calculate several team tactical performance measures for each sample of time. The team centroid is the average position of each outfield player on the pitch (Frencken & Lemmink, 2008). Distance between team centroids in the longitudinal (X) direction is the inter-team distance (Frencken et al., 2013). The average longitudinal and lateral (Y) distance of each player to this team

centroid is the longitudinal and lateral stretch index, respectively (Bourbousson et al., 2010). The maximal distance between players in the longitudinal and lateral direction is used to calculate the length and width of the team, respectively. The ratio between length and width is the length-per-width (LPW) ratio (Folgado, Lemmink, et al., 2014). The surface area of each team was calculated as the area of the convex hull (Frencken, Lemmink, Delleman, & Visscher, 2011). All team tactical performance measures were calculated for the effective playing time.

Running correlations of team centroids and dispersion measures of opposing teams were calculated over a 3-second moving window to determine coordination patterns of the effective playing time (Corbetta & Thelen, 1996; Frencken et al., 2013). Coordination patterns were considered as in-phase ($1 \leq r < 0.5$), no interaction ($.5 \leq r \leq -.5$) or anti-phase ($-.5 < r \leq -1$).

Statistical analyses

A customized *R* routine is used to conduct statistical analyses (*R* for Windows 324, R Foundation for Statistical Computing, Vienna, Austria). Data were checked on quality and normality. Five players were excluded in one under-19 match, because their sampling frequency fluctuated during data collection. Therefore, their physical performance and the tactical performance measures of the corresponding team were left out of the analysis. Furthermore, visual inspection of boxplots of physical performance revealed that another five players were outside the inter-quartile range and were therefore considered as outliers. Their data were removed from further analysis.

Means and *SD*s were calculated for game characteristics, physical performance, technical performance and team tactical performance and corresponding interaction patterns. Multivariate analyses of variance (MANOVAs) (Pillai's Trace) were calculated to test for differences in game characteristics, physical, technical and team tactical performance between the official match and training game. Univariate analyses of variance were conducted when a main effect was detected. Significance level was set at 5%. Eta-squared (η^2) values were calculated and used to determine the effect size (Levine & Hullett, 2002). Magnitude of these effects were considered as small ($\eta^2 < 0.06$), moderate ($0.06 \leq \eta^2 < 0.15$) or large ($\eta^2 \geq 0.15$) (Cohen, 1988). Confidence intervals (CIs) of 95% were provided for differences between match and training game.

Results

Results from the MANOVAs revealed significant differences between the official match and training game for game characteristics ($F = 20.27$; $p < 0.001$), physical performance ($F = 90.05$; $p < 0.001$), technical performance ($F = 6.88$; $p < 0.05$), and team tactical

performance (F = 11.53; p < 0.001). In the official match, there was significantly less relative playing time than in the training games and duration of ball possession was reduced (table 5.1). This resulted in a significant higher rate of transitions of ball possession in the match than in the training. Effect sizes for all game characteristics were large.

Physical, technical and team tactical performance measures differed between the official match and training. Players covered significantly more distance (F = 237.1; p < 0.001; η2 = 0.33; CI -28.9 to -22.1) and sprinted more often (F = 6.3; p < 0.05; η2 = 0.01; CI -0.1 to 0.0) in the match than in the training, but differences in HID were not significant (F = 0.0; p = 0.9; η2 = 0.01; CI -0.4 to 0.6) and the magnitude of the effect for sprints per minute was small (figure 5.1). Game pace was significantly lower in the official match with a large effect size (F = 14.4; p < 0.001; η2 = 0.36; CI 1.1 to 3.7), expressed as a lower number of passes per minute. On average, there was a higher error percentage of passes in the official match than in the training game, but this effect was small (F = 5.3; p < 0.05; η2 = 0.02; CI -11.0 to -0.6; figure 5.1). For the team tactical performance, only LPW ratio was higher in the match with a large effect size (table 5.1). Other inter-team and intra-team distances were similar between the training and match.

Large proportions of in-phase behavior were found for all team tactical variables (table 5.1). And, significant higher in-phase relations were found in the match for width, lateral stretch index and surface area, but other in-phase pattern did not differ between match and training for other tactical variables. Further analysis of the interaction patterns revealed that there was a significant lower anti-phase behavior in the match for the longitudinal team centroid, width and lateral stretch index with large effect sizes.

Table 5.1. Mean and SD and test statistics with the F-value, p-value, effect size (η^2), and 95% confidence interval (CI) of game characteristics, team tactical performance and interaction patterns.*

		Match	Training				
Game characteristics		Mean ± SD	Mean ± SD	*F*	*p*	η^2	CI
Game duration (min)		45.1 ± 3.1	10.0 ± 0.9			*n/a*	
Effective playing time (min)		30.5 ± 3.3	8.7 ± 1.1			*n/a*	
Relative playing time (%)		67.7 ± 6.4	86.9 ± 6.4	60.16	<0.001	0.71	-32.7 : -17.4
BP duration (s)		8.7 ± 1.1	14.0 ± 1.9	69.81	<0.001	0.74	-6.4 : -3.4
Transitions per minute		6.4 ± 1.7	4.4 ± 0.5	20.50	<0.001	0.45	1.7 : 3.2
Team tactical performance							
Inter-team distance (x) (m)		5.4 ± 0.4	5.4 ± 0.8	.00	1.0	0.00	-0.2 : 2.4
Length (m)		34.8 ± 1.6	33.6 ± 1.9	3.14	0.1	0.07	-0.2 : 2.4
Width (m)		41.6 ± 2.7	43.0 ± 1.9	3.03	0.1	0.07	-3.0 : 0.2
LPW ratio (AU)		0.9 ± 0.1	0.8 ± 0.1	7.31	<0.05	0.15	0.0 : 0.1
Stretch index (x) (m)		10.1 ± 0.4	9.7 ± 0.6	3.22	0.1	0.07	0.0 : 0.1
Stretch index (y) (m)		11.1 ± 0.8	11.3 ± 0.5	.73	0.4	0.02	-0.2 : 2.4
Surface area (m^2)		1035.0 ± 104.4	1011.9 ± 84.2	.51	0.5	0.01	-3.0 : 0.2
Interaction patterns (%)							
	In	88.5 ± 9.8	90.2 ± 3.0	2.89	0.1	0.12	0.4 : 3.8
Centroid (x)	No	5.0 ± 0.9	5.5 ± 1.2	.28	0.6	0.01	-1.2 : 0.7
	Anti	2.7 ± 0.8	4.3 ± 2.0	4.90	<0.05	0.18	-2.9 : -0.1
	In	84.5 ± 9.7	86.9 ± 3.0	1.32	0.3	0.06	-1.0 : 3.5
Centroid (y)	No	7.3 ± 1.3	7.9 ± 1.1	1.04	0.3	0.05	-1.5 : 0.5
	Anti	4.4 ± 1.0	5.2 ± 2.3	1.00	0.3	0.04	-2.3 : -0.8
	In	59.5 ± 6.4	60.8 ± 3.2	0.09	0.8	0.00	-2.3 : 3.1
Length	No	18.7 ± 2.3	19.6 ± 1.6	0.10	0.8	0.00	-1.4 : 1.1
	Anti	18.0 ± 3.6	19.6 ± 2.4	0.04	0.9	0.00	-2.4 : 2.0
	In	47.4 ± 7.0	45.0 ± 3.4	5.41	<0.05	0.20	0.5 : 8.4
Width	No	20.2 ± 2.8	20.9 ± 1.2	0.16	0.7	0.01	-1.6 : 1.1
	Anti	28.6 ± 5.3	34.1 ± 3.4	5.46	<0.05	0.20	-7.9 : -0.5
	In	55.8 ± 6.4	59.1 ± 3.7	0.95	0.3	0.04	-4.4 : 1.6
LPW ratio	No	20.5 ± 2.7	21.2 ± 1.9	0.01	0.9	0.00	-1.6 : 1.5
	Anti	19.9 ± 3.3	19.7 ± 3.0	1.52	0.2	0.06	-1.0 : 3.9
	In	63.8 ± 6.9	64.3 ± 3.5	1.04	0.3	0.05	-1.4 : 4.1
Stretch index (x)	No	16.8 ± 2.3	18.1 ± 1.7	0.53	0.5	0.02	-1.8 : 0.9
	Anti	15.5 ± 2.6	17.6 ± 2.6	0.84	0.4	0.04	-2.9 : 1.1
	In	56.4 ± 7.0	53.8 ± 2.9	13.45	<0.05	0.38	2.2 : 7.9
Stretch index (y)	No	17.5 ± 2.3	18.4 ± 1.3	0.20	0.7	0.01	-1.5 : 1.0
	Anti	22.3 ± 3.6	27.9 ± 2.7	14.68	<0.001	0.40	-7.3 : 2.2
	In	54.0 ± 6.4	52.0 ± 3.7	5.03	<0.05	0.19	0.3 : 7.1
Surface area	No	18.0 ± 2.6	19.1 ± 1.4	0.87	0.4	0.04	-1.9 : 0.7
	Anti	24.1 ± 4.7	28.9 ± 3.6	3.76	0.1	0.15	-6.4 : 0.2

* BP = ball possession; LPW = length per width

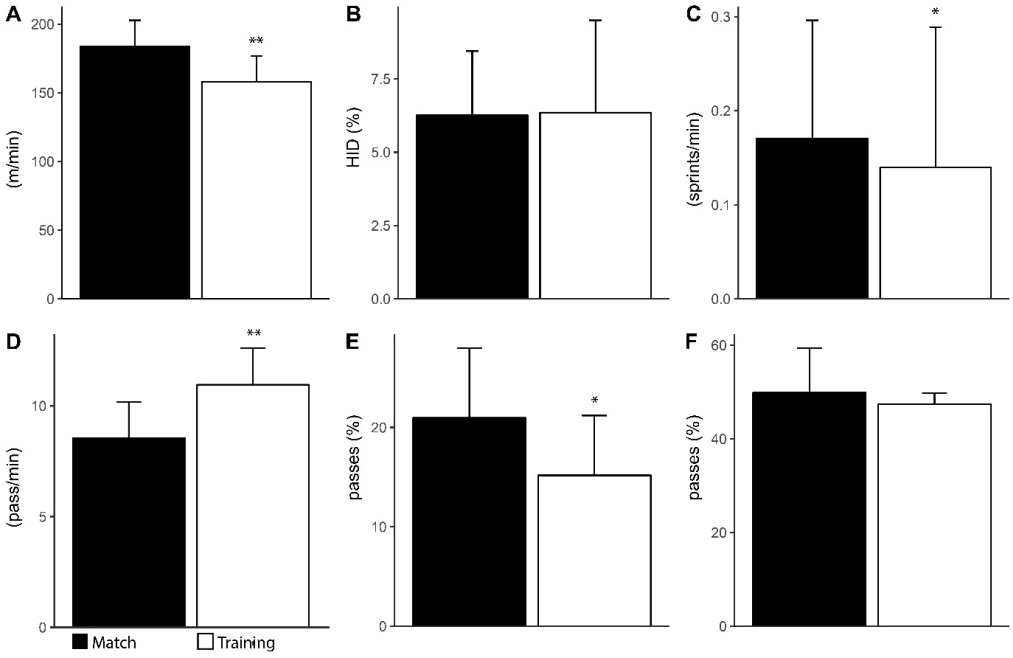

Figure 5.1. Physical (A. distance covered; B. high intensity distance; C. sprints) and technical performance measures (D. game pace; E. incorrect passes; F. forward passes) in the official match and training game. Significantly different from the match (*p<.05 and **p<.001).

Discussion

The aim of this study was to investigate soccer performance in official matches and 11 vs. 11 training games with an integration of physical, technical and team tactical performance. In a complex game like soccer, there is a continuous interplay of physical, technical and team tactical performance during the game (Hill-Haas et al., 2011). Differences in the constraints in the official match, like task duration, higher levels of anxiety, expectations of the crowd and a different purpose (Glazier & Robins, 2013; Newell, 1986), affected soccer performance compared to a similar format in the training game. In particular, physical and technical performance measures differed between the match and training, and some differences were present in team tactical behavior. In addition, game characteristics were different, displayed by less relative playing time and shorter ball possession duration, but more transitions per minute in the match. It is therefore important to correct performance for this difference in effective playing

time and only include performance when the ball was actually in play for an adequate comparison of performance between match and training.

Physical and technical performance, both measures of individual performance, were different in the match compared to the training. Players covered on average more distance and sprinted more often in the match. Also the technical performance significantly differed in the match: pace of the game was lower, displayed by less passes per minute, and players made more errors in passing. The influence of a different set of constraints on both physical and technical performance can be explained in two ways, using the model of Nieuwenhuys & Oudejans (2012). A performance decrement is displayed by the ball carrying players. In the match, they seemed to face difficulties perceiving soccer-relevant information (i.e. pass options from team members), selecting pass options (i.e. knowing whether a team member is a pass option) or executing the pass (i.e. passing with the wrong speed or in the wrong direction). By contrast, the match constraints had a positive outcome on physical performance and on the technical performance of opponent players. Players covered more distance and conducted more sprints. Moreover, players of the opponent intercepted the ball more often. Furthermore, differences in task duration could have contributed to our results. However, contrary to the logical expectation that a shorter training game duration results in higher physical performance, current results demonstrate a less physically demanding training game. Possibly, players do not give their maximum performance in training like they would do in the match. The bout duration and repetition in this design preserves the ecological validity of a training context and is appropriate for daily soccer practice, instead of 2 x 45 minutes of a match. To sum up, despite a strong expectation of differences in physical and technical performance as a result of typical match constraints, causality of this behavior is difficult to prove.

Although individual performance differed much between match and training, this seemed less present on team level. During the match, the LPW ratio was larger and approached a value of 1. This implicates that the shape of the teams changed toward a more squared shape in the match instead of a more rectangular shape in the lateral direction in the training. In the match, when it is assumed that something was at stake, the orientation of a team changed toward the goal of the opponent and less in the width of the pitch. Other intra-team measures were not affected in the match and also the inter-team distance did not change. Most of these measures are dependent on the team centroid and, possibly, less sensitive for changes in 11 vs. 11 situations where they do tend to change in small-sided games (Bartlett, Button, Robins, Dutt-Mazumder, & Kennedy, 2012). Where the effect of a different set of constraints was present in individual performance, it may wash out in team performance.

In soccer, there is a continuous interaction between the two opposing teams (Grehaigne et al., 1997). If one team is in possession of the ball and tries to score a goal, the other team tries to prevent this and recover ball possession. High proportions of in-phase behavior in all team tactical measures are an indication that teams moved in the same direction over the pitch and increased and decreased their dispersion in a synchronized manner. This is in accordance with dominant interaction patterns in small-sided games (Frencken et al., 2013; Olthof, Frencken, & Lemmink, 2015). Differences in coordination behavior between match and training games were found in the longitudinal team centroids, width, lateral stretch index and surface area. Longitudinal team centroids moved less in an opposite direction, displayed by a decrease in anti-phase coupling. Higher in-phase couplings were found for the width and lateral stretch index in the match with, consequently, a lower anti-phase coupling. Also the coupling in surface area showed an increase in in-phase coupling. These are indications of more simultaneous increase and decrease of the dispersion in the match, mostly related to a lateral orientation. Results in this study are in line with findings of Folgado, Duarte et al. (2014), where they found an increase in intra-team synchronization in matches competing against higher-level opponents. They suggested that more synchronization is an indication for increased collaboration within a team in order to enhance performance. Coordination between teams did change 'when something was at stake'. Most likely, the match constraints evoked a slightly tighter coupling between teams than the training.

In this study, several personal and environmental constraints were considered to have impact on matches and training games. It was aimed to preserve the ecological validity of match and training as much as possible and this resulted in some practical consequences. Some players were team members during the match, but opponents in the training game. Another consequence was that prematch preparation (e.g., rest day or light training) was not taken into account compared to training. These features add to the personal and environmental constraints in match and training and might have contributed to the differences in performance and can be considered as limitations of this study.

To conclude, soccer performance is a result of an interplay of physical, technical and team tactical performance and this performance differed between the official match and training. Differences in constraints as a result of task duration and the consequence of winning or losing, described by anxiety levels, pressure of the crowd and the purpose of winning instead of developing skills, may account for these differences. Following the natural flow of soccer, an integration of the most important soccer performance indicators is necessary to explain these changes. Starting from a ball carrier perspective, players made more mistakes on the ball, resulting in more

shifts of ball possession between teams. And players covered more distance and sprinted more often. Team dispersion changed toward a more longitudinal orientation and teams were tighter coupled. The latter is an indication that there were less opportunities to break movement synchronization patterns. These results confirm intentions of soccer coaches that 11 vs. 11 in training is mainly used to replicate the tactical aspect instead of a physical stimulus, although there were some technical and team tactical differences between an official match and a training game.

Practical Applications

Results of this study confirm the intentions of soccer coaches to use 11 vs. 11 in a practice setting to mimic team tactical behavior of an official match. In this training setting, players perceive and pick up information from their team members, opponents and the ball in a context similar to the match. So, similar tactical behavior will be trained in 11 vs. 11, despite a different opponent, crowd presence and different levels of anxiety.

In addition, when coaches would be able to increase the importance of winning and losing in a training game, they would improve representativeness of the 11 vs. 11 training game for the official match. Following the recommendations of Headdrick et al. (2015), putting emphasis on these constraints will effectively simulate the demands of an official match. Results showed that predominantly physical performance differ between training and match. Most likely, physical intensity will increase as a result of emphasizing on the importance of winning in practice, but also technical and team tactical performance and interactions between team will be more representative for the official match. To raise the stake in a training context, trainers could include playing in front of a crowd, with a referee, or set up an internal competition.

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CHAPTER 6

General discussion

Thesis aim

Small-sided games are a popular training format across all age groups and playing levels. They aim to improve individual performance and collective behavior simultaneously. It is therefore a representative training format in order to optimize the learning process of playing soccer. Small-sided games are well known for their adaptable features: manipulations of pitch size, number of players, and playing rules can be used to meet a desired training purpose or to adapt to the available number of players or training area. Although there is an infinity in small-sided game designs, they all have in common that players cooperate and compete with each other in two teams in order to score goals. A widely-used assumption – both in science and practice – is that small-sided games represent the official match. However, this claim lacks adequate scientific support where improvements can be made such as consistent manipulations in multiple small-sided games and across age groups.

This thesis aimed to investigate if and how small-sided games represent the official match in elite youth soccer. Therefore, pitch size (two different relative pitch areas) and number of players (varying from small to large teams) were manipulated and played by different age categories (varying from under-13 to under-19). By doing so, individual performance and team tactical behavior in official matches and small-sided games were determined in elite youth soccer. The principles of a relative pitch area were applied in order to design the pitch sizes of small-sided games and express the individual playing area in these games and the official match. Each team played five small-sided games in traditional and experimental formats during training. The traditional game was played as a 5-a-side game on a 40 x 30 m pitch, corresponding to 120 m^2 relative pitch area. The four experimental games were 5, 7, 9, and 11-a-side games played on a match-derived (i.e., 320 m^2) relative pitch area. Official playing rules were applied with exception of the offside rule in the traditional small-sided game. During the small-sided games, positional data and video footage were captured in order to determine physical and technical performance of individual players and team tactical behavior. In addition, similar data were collected during official matches (at least two per age group). This has resulted in recordings of 16 matches and 189 small-sided games (in 48 training sessions) of 12 academy teams (with 319 unique players).

Summary of the key findings

Age and different pitch sizes influence the performance and behavior in 5-a-side games in various ways. First, it was found that the under-19 team used a wider player distribution than the under-17 team, but both teams showed similar interaction patterns playing the same traditional 5-a-side game (chapter 2). Second, individual

performance and collective behavior changed in 5-a-side games on a large pitch versus a small pitch (chapter 3). This was displayed by greater physical performance and increased intra-team and inter-team measures. Third, on a larger pitch, older teams showed greater increase in physical performance and inter-team distances, whereas younger teams showed a greater increase in intra-team distances (chapter 3).

Then, the official match was included to the research in order to compare this match with various small-sided game formats played on a match-derived relative pitch area. This led to various results. First, intra-team measures increased and tactical variability decreased with an increasing number of players in a team (chapter 4). Second, the structure and dispersion within teams (i.e., sub-groups) were similar across the small-sided games (chapter 4). Third, teams showed similar collective behavior in 11-a-side games as in the match in general (chapter 5). However, the match context was more physically demanding and ball carrying players showed less accurate passing in the match.

A small-sided game represents the official match

In order to address the claim that "small-sided games represent the official match", the performance and behavior in small-sided games and official matches were determined. First, the interaction between teams in traditional 5-a-side games was investigated and this revealed a dominant behavior of team centroids moving in the same direction for the greater part of these small-sided games. These movements patterns of team centroids were similar to Frencken et al. (2011) and slightly greater than Frencken et al. (2013) in 5-a-side games. A tight coupling, also referred to as in-phase behavior, is dominant between team centroids and team areas. This shows that teams follow each other in a similar direction on the pitch. In order to deal with the competitive relation between teams and corresponding conflicting interests, teams follow each other tightly across the pitch. Furthermore, team areas simultaneously increase and decrease in order to reduce the opportunities for the attacking team. Together with inter-team and intra-team distances, these analyses are able to capture collective behavior in these traditional 5-a-side games.

However, these small-sided games were played on pitch areas much smaller than the match which possibly affects match representation. Therefore, a match-derived relative pitch area (i.e., 320 m^2) was applied to the 5-a-side game in order to observe the effect on behavior compared to the traditional pitch size (chapter 3). Such a playing area was only used once to investigate physical performance (Castellano, Puente, Echeazarra, & Casamichana, 2015). Playing small-sided games on this pitch area resulted in increased intra-team and inter-team distances and tactical variability. As shown by previous research on pitch size manipulation, a larger pitch affords players

more space to explore and occupy, which results in a greater player distribution. Accordingly, tactical variability increases, which reflects larger changes in interpersonal distances and dispersion. This behavior is typically associated with the increase of space when teams are in attack, a decrease of space when teams are in defense, and the transition between those phases. Moreover, in order to facilitate the increase and decrease in team dispersion, players run more and at higher speed. By contrast, a small pitch constrains players to stay close to each other and this limits their movement behavior. To illustrate, players did not perform sprints on a small pitch. The differences in pitch size account for different behavior. This finding suggests that pitch size can influence the representative character of small-sided games.

Subsequently, official matches were included in order to compare behavior in competition with small-sided games played on a match-derived relative pitch area. With a correction for the difference in number of players (i.e., using sub-groups based on player positioning), this inclusion revealed that on average the distance maintained by players during the small-sided games and the match is similar, i.e. 9 – 12 meters to their nearest team member (chapter 4). This distance is larger than in small-sided games with a smaller pitch size. Apparently, on a match-derived pitch area, players are able to choose position and maintain a similar structure in their team as in the match. A small-sided game with a match-derived relative pitch area seems more representative for collective behavior in the match. However, match pressure accounts for specific constraints which differ from an 11-a-side game. Probably, a consequence of winning or losing creates a rise in levels of anxiety which results in specific match behavior. This mainly affected individual performance and there was some influence on collective behavior (chapter 5). The match stresses physical and technical performance for a considerable part and contributes to greater coupling between teams.

Concluding, individual performance and team tactical behavior in small-sided games mimic the official match, but a smaller relative pitch area decreases the physical demands, intra-team and inter-team distances, and tactical variability. A match-derived relative pitch area in small-sided games enhances the representation of performance and behavior with respect to the match. However, the individual performance is affected by a specific set of match constraints.

Number of players

Besides pitch size, coaches typically manipulate the number of players in small-sided games. Logically, the spatial distribution of players on the pitch differs along with the number of players in a team. Larger team lengths, widths and surface areas were found by an increase in number of players on the pitch (chapter 4). This was already

established in teams up to five players (Silva, Vilar, Davids, Araújo, & Garganta, 2016), and it is demonstrated that it also holds for teams with five players and more. In addition, more players on the pitch decreased the tactical variability. Possibly, intra-team distances of larger teams are less sensitive for changes and players need to coordinate their behavior with more players in their proximity (Silva et al., 2016). More players in a team indicate less positional changes of players and a smaller increase and decrease of a team's space. Simultaneously, the spatial dispersion within sub-groups was comparable between the small-sided games and the match, despite age-related differences in some formats. Similarities between the sub-groups imply that players are able to adapt to a different number of players and maintain a preferable distance to their team members.

In addition, manipulation of the number of players typically affects the technical performance (see for reviews Aguiar, Botelho, Lago-Peñas, Maçãs, & Sampaio, 2012; Hill-Haas, Dawson, Impellizzeri, & Coutts, 2011). Chapter 4 revealed that the number of individual ball involvements increased if there are less players on the pitch. A 5-a-side game stresses the technical capacities of a player more than the match, illustrated by 262% more passes. Small-sided games played by a reduced number of players put a greater emphasis on technical performance. Players are more involved in passing in formats with small teams. As the interpersonal distances are similar to the match, these passes are performed over similar distances. So, taken all together, an increase in number of players results in a decrease in tactical variability and technical actions per player, but a similar spatial distribution of players when corrected for pitch size.

Age-related differences

Besides the manipulations in pitch size and number of players, a player's age contributes to individual performance, and intra-team and inter-team coordination. Under-19 teams demonstrated a wider player distribution in a traditional 5-a-side game than under-17 teams (chapter 2). In combination with pitch size manipulations, age-related differences are increasingly present (chapter 3). A large pitch results in larger inter-team and intra-team distance across all age groups compared to a small pitch in 5-a-side games. As the age increased, the distance between teams showed the largest increase on a large compared to a small pitch. Younger teams showed the largest increase in player distribution within teams on a large compared to a small pitch. Both chapters demonstrate that older soccer players try to adopt a wider dispersion on the pitch and (literally) explore the boundaries of the available playing area. They use the available playing area with a greater player distribution than their younger peers. This behavior is likely facilitated by increased physical capacities, as older players are more

capable to cover distances at high intensities (Buchheit, Mendez-Villanueva, Simpson, & Bourdon, 2010; Goto, Morris, & Nevill, 2015), pass the ball over larger distances with more accuracy and discover a wider range of players as opportunities to cooperate (Williams, 2000). Smaller distances within teams suggest that younger players are more inclined to play closer to the ball and each other, but can benefit from a larger pitch size in order to attune to larger playing areas and adopt a wider dispersion.

A player's age also influences the relation between small-sided games and the official match (chapter 4). Under-13, under-15, and under-17 teams showed larger distances between players in the 5-a-side games than in the match. By contrast, under-19 teams showed smaller distances between players in the larger small-sided games (i.e., 7-a-side and 9-a-side) than in the match. A likely explanation for this is that older soccer players have more years of experience in playing a full-sized match and are therefore more accustomed to the larger playing area. A reduction in absolute pitch length might have constrained them in maintaining a similar player distribution. Younger soccer players, on the other hand, make the switch to playing a full-sized match from playing matches on a smaller pitch with smaller teams, like 7 vs. 7 on a half-sized pitch and smaller playing areas as a consequence. Players of different age categories are differently attuned to their team members, opponents, and the pitch area. This resulted in a different relation between the match and the small-sided game across age groups.

Match pressure

Specific sets of constraints are related to the match and training context. Besides the official FIFA regulations, an official match is defined by factors related to match pressure: a consequence of winning or losing, anxiety, crowd pressure, and a relatively unknown opponent. Findings in chapter 5 showed that in general, intra-team and inter-team distances in the match were comparable to the 11-a-side game. However, the coupling strength increased. Teams moved more coordinated in the length and the width over the pitch during match than during training. Teams mimic each other's movement behavior in order to obstruct the shortest path towards the goal, but they also mimic each other's movements in the width of the pitch. Possibly, the impact of a consequence of winning or losing causes that teams are more tightly coupled in all directions (Folgado, Duarte, Fernandes, & Sampaio, 2014). This leads to greater physical demands, to a decrease in possibilities to pass the ball to team members and therefore, to a decrease in passing accuracy in the match. Altogether, the specific set of match constraints specifically elicits behavior. This possibly defines goal-directed behavior, like tighter couplings between teams and a physically more demanding context.

In addition, detailed analysis of the game characteristics revealed that there is less effective playing time during the match than during the training (chapters 4 and 5). A match is typically known for a decrease in playing time towards the end of the game, due to (strategically planned) substitutes, (feigned) injuries and set pieces that take more time to resume the game (Derbyshire, Angel, & Bushell, 2016). During small-sided games, 84% of the time was used on average to play the game, but this proportion was reduced to 70% during the match. Taken together, specific constraints arise from the match context that are different in the training context. This results in altered game characteristics and individual performance, but a similar collective behavior in small-sided games.

Strengths and limitations

This thesis responded to the widely used – yet insufficiently supported – statement that "small-sided games are a representation of the official match". Three major strengths can be identified from this thesis, in regards to i) representation, ii) (match-derived) relative pitch area, and iii) the design.

In previous research, a small-sided game was considered as a representation of the match, because two teams have the opportunity to score goals and there is an interplay of physical, technical, and tactical performance. The term 'representation' can benefit from consensus on which variables or constraints the small-sided game should replicate (Farrow & Robertson, 2017). This thesis considered a small-sided game as an adequate representation if the distance covered, number of passes or interpersonal distance are similar to the values of the match. That is, if no significant differences and moderate to large effect sizes were established. Then, players act under the regulations of a match (e.g., pitch markings, playing rules), rely on their decision-making skills (e.g., have the option to pass the ball to several available team members, to dribble or to shoot), and take action if opponent players attack the goal (e.g., use man-marking or zone-marking and collaborate with team members to collectively defend). In such training games, soccer behavior better replicates the match and the format becomes a more meaningful context for the player.

A meaningful representation can be achieved by using a match-derived relative pitch area in small-sided games in order to create an optimal learning environment. For training games with these playing areas, it was already established that physical performance mimics the demands of the match (Casamichana & Castellano, 2010; Castellano, Puente, Echeazarra, Usabiaga, & Casamichana, 2016). Findings in this thesis add that also collective behavior show similarities with the official match. A match-derived relative pitch area can be applied to small-sided game formats with different

number of players to enhance representation for the match. These formats contribute to an extension of the current training program in soccer practice, where these small-sided games can be applied to train more specifically for the match.

In this thesis, manipulations were consistently carried out in various small-sided game formats, data were collected during multiple official matches and training sessions, and four age categories participated of three Dutch professional youth academies. This has resulted in a comprehensive dataset containing 16 competitive matches, 189 small-sided games during 48 training sessions of 12 academy teams. It is a very robust dataset compared to other studies where only one small-sided game was used. As physical performance varies over consecutive games (Gregson, Drust, Atkinson, & Di Salvo, 2010; Rampinini, Coutts, Castagna, Sassi, & Impellizzeri, 2007), a series of matches and small-sided games were played to account for the variability. In addition, accurate positional data were collected with a high sample frequency in order to be able to accurately determine tactical behavior. Finally, access was granted to a high number of good quality players and teams in order to determine individual performance and collective behavior for elite youth soccer. Altogether, findings of this thesis contribute to a meaningful understanding of soccer behavior in elite youth soccer.

In contrast to these strengths, two limitations can be identified in this thesis with regards to i) integration of performance variables, and ii) exploration of different temporal patterns. First, this thesis attempted to integrate physical and technical performance variables with team tactical measures because of the unique design of the study. However, as this integration was not completed throughout each chapter, future studies could continue using holistic approaches to provide further insights into the interplay of physical and technical performance with team tactical behavior. Second, this thesis was predominantly focused on the spatial patterns of inter-team and intra-team distances. Besides the importance of these spatial distributions of players on the pitch, there is strong evidence that further exploration of temporal movement patterns can contribute to better identification and capture of goal-directed behavior as proposed by Memmert, Lemmink & Sampaio (2017). Although analyses in this thesis provided insights into interaction patterns and tactical variability during matches and small-sided games, future research is needed to further explore the temporal coordination patterns of players and teams. Advances can add to a more comprehensive overview of soccer behavior in small-sided games and official matches and may contribute to further unraveling the complexity of soccer.

Conclusion

To conclude, a small-sided game played on a match-derived relative pitch area enhances the representation for the official match. In such formats, the official playing rules can be applied. Players demonstrate similar team tactical behavior in these training formats as the match and the physical demands mimic the match demands (figure 6.1.). Yet, the influence of number of players, age, and match pressure on the degree of representation are inherent to the definition and application of a small-sided game. Findings of this thesis provided insight that i) a reduction in number of players enables teams to maintain a preferable team organization, ii) the relation with the match is different per age group, and iii) a small-sided game lacks match pressure for an optimal representation. Given the fact that these small-sided games possess features of the match, the conclusion can be made that it is all in the game.

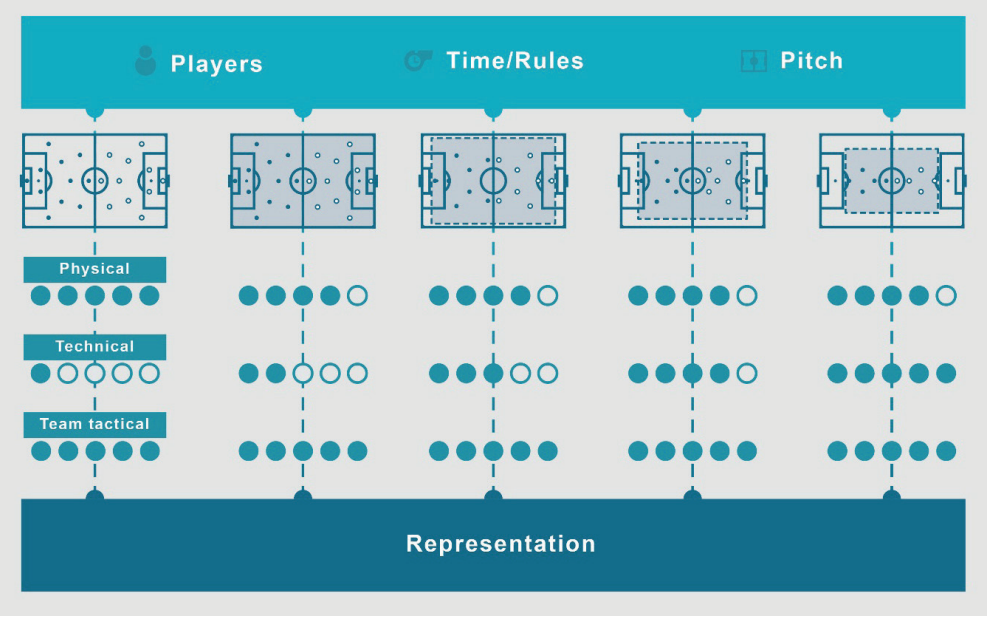

Figure 6.1. A schematic display of the representative character of a small-sided game for the official match on the physical, technical, and team tactical variables used in this thesis. Filled and open dots are inferred from findings in this thesis. Small-sided games were played on a match-derived relative pitch area with official playing rules (and a different number of players).

Scientific implications

The concept of the representative learning design (Araújo & Davids, 2015) combined with principles from ecological dynamics (Grehaigne, Bouthier, & David, 1997) and the constraint-led approach (Glazier & Robins, 2013) resulted in a framework for this thesis. Team tactical measures as conceptualized by Frencken (2012) along with several spatio-temporal, time-motion, and notational analyses were applied to determine soccer behavior. This was necessary to give a comprehensive overview of behavior in small-sided games and the official match, as soccer is considered as an interplay of physical, technical, and tactical skills of players. This has brought several implications for soccer science.

First, this thesis made a first step to compare individual performance and collective behavior in small-sided games with the official match. Despite a growing body of literature in soccer science and a widely-used assumption, there was a lack of scientific support for the representative character of the small-sided games. Subgroups of two and four players were used in order to enable the comparison of small-sided game formats with the match.

Second, the spatio-temporal analyses previously developed in several team sport studies (e.g., soccer, basketball, rugby-union) have been applied in order to capture goal-directed behavior in several small-sided game formats and the official match. A next step to fully capture goal-directed behavior is further exploration of temporal movement patterns, like relative phases in teams coordination and (ir) regularity of play. A better understanding of goal-directed behavior can ultimately result in the definition of performance achievement (Araújo & Davids, 2015). In order to facilitate this process, soccer science should define successful collective behavior or team tactical performance.

Third, the representative learning design is relatively unknown in soccer science, but it is useful to optimize small-sided game formats to enhance the learning process of soccer. The small-sided games act as the learning environment, whereas the match is the performance context. The design enabled the confirmation of the claim 'small-sided games represent the official match'. Future studies should focus on the other side of the learning process: if and how a transfer is made from training to match (Araújo & Davids, 2015). Scientific challenges lie ahead to create criteria to measure transfer from training to the match setting.

Fourth, in order to optimize a small-sided game as a representative learning design, the concept of a relative pitch area has been implemented in multiple small-sided games. Besides a previously established physical replication (Casamichana & Castellano, 2010; Castellano et al., 2015), this concept confirms that collective behavior can be replicated as well in small-sided games played on a match-derived relative pitch area.

Practical implications

This thesis has predominantly focused on a specific small-sided game format with a match-derived relative pitch area. However, a variation of small-sided games is necessary to emphasize specific situations of the official match. Training benefits from a variation in training formats in order to provide an accurate stimulus and to enhance the learning process of soccer. Moreover, variation in small-sided game formats (e.g., both pitch size and number of players) elicits a variability of action possibilities and behavior. In this thesis, two pitch sizes were highlighted, classified as 'small' and 'large'.

Small pitch sizes are often used to 'act quickly under the pressure of time'. In practice, this format mainly focuses on the ball carrier and the nearest defender. It challenges the ball-carrying player to make a quick decision. Time is limited, because a defender is nearby to take over the ball. Other players, however, are restricted in their opportunities. Typically, there is not a lot of space on the pitch to run and become available as a pass option for the ball-carrying player. The players of the defending team, on the other hand, are – already – standing close to each other. However, it does not challenge them to make an effort in restricting space, because they are positioned to stand close to each other. In addition, players do not perform sprints on these pitches. Overall, tactical variability is reduced and ball possession quickly goes back and forth between the teams (chapter 3). Small pitches are an excellent training format to practice quick ball actions and emphasize on the transition between attack and defense.

Large pitch sizes are suitable if the training is focused on tactical variability and a physical stimulus. The distance between players is larger and more variable, and there is more space on the pitch that elicits players to explore. For a ball-carrying player, the distance for a pass is similar to match. In more detail, the player is probably challenged to choose from multiple options: pass the ball to his team member directly, slightly in front of him when approaching the opponent goal, or pass the ball – through the air – to the zone between the defending line and goalkeeper. The defending team, on the other hand, is challenged to collectively defend more space on the pitch. They are challenged – after a transition – to get into a defending organization and maintain preferred distances. Typically, a soccer coach allows a 3-second window to reorganize into a defending setting (Frencken et al., 2013). In addition, the collaboration between a goalkeeper and defending line must be matched to respond to a ball in the open space between them. Concluding, the choice for a larger pitch results in a practice for the attunement of defending and attacking strategies, variety in action possibilities and a physical stimulus.

In addition to the pitch size, a decrease of the number of players stresses the technical demands of a small-sided game: more ball contacts per player. More

specifically, a 9-a-side, 7-a-side and 5-a-side game result in 162%, 225% and 263% more passes per minute per player, respectively. If a coach aims to play a small-sided game on a similar playing area as the match with less players, he/she may consider to reduce playing time to compensate for the greater technical stress.

Altogether, small-sided games can be used to address training goals related to match situations and enhance the learning process in soccer as such. A training program with sufficient variation in pitch size and number of players affords varying training stimuli, a shift in focus on either physical, technical or tactical performance, and coaches can augment specific match situations (see figure 6.1.). In preparation for either a single small-sided game or a training program (e.g. multiple weeks or an entire season), soccer coaches may carefully consider the pitch size and number of players tailored to the training goal and the age of their players.

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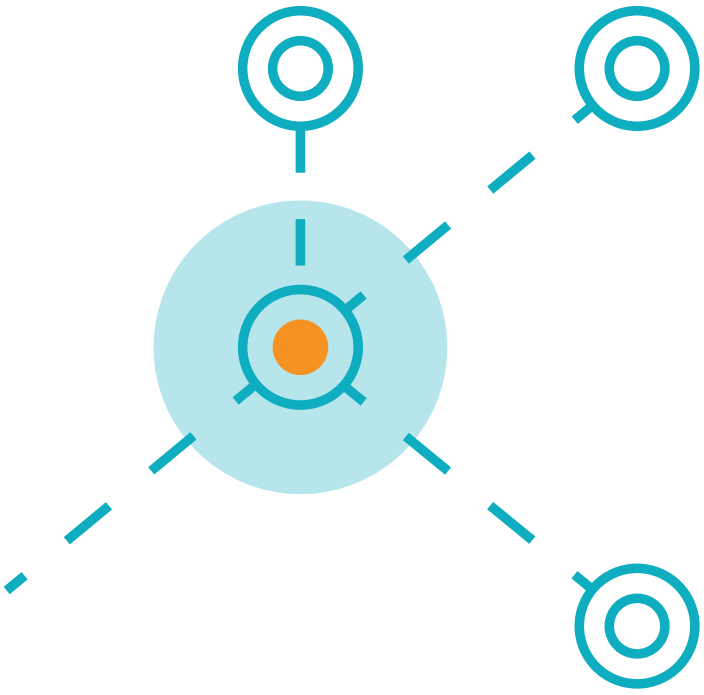

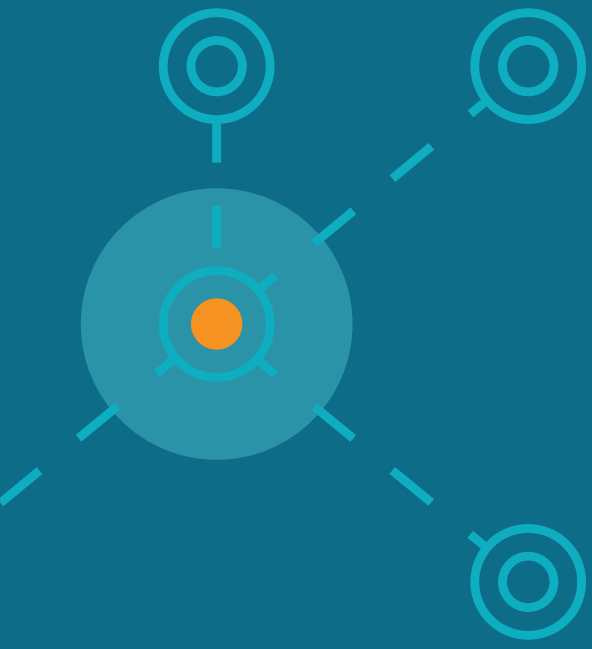

APPENDICES

Summary

The present thesis investigates small-sided games in youth soccer. These training formats are used in daily soccer practice in order to develop soccer skills, prepare players for the official match, and enhance the learning process of soccer. Varying pitch sizes and number of players per team in small-sided games influence individual performance and team behavior. A comparable playing area as the match can contribute to an optimal representation of a small-sided game for the match.

Pitch size, number of players, and playing rules are fixed in the regulations of the match, but provide endless combinations for a small-sided game. These characteristics constrain the individual performance and team behavior in soccer. In particular, manipulations in pitch size and number of players in small-sided games have impact on players' behavior and different age groups respond differently to these manipulations. A theoretical basis and experts' view of individual performance and team behavior in official matches, small-sided games, and youth soccer is provided in chapter 1 taking these constraints into account. Yet, it is still claimed – in science and practice – that small-sided games represent the official match. Inherent to the definition and application of a small-sided game, it is on debate if and how such small-sided games mimic the performance and behavior in the official match. For the purpose of this thesis, a series of small-sided games are played where pitch size (using two relative pitch areas), number of players (varying from small to large teams), and age (varying from younger to older age groups) have been manipulated in order to investigate performance and behavior and the relation with the official match. A comparable playing area as in the match may enhance the representation of small-sided games, regardless the number of players. Match pressure and age may influence the relation between small-sided games and the match and should therefore be evaluated carefully.

The influence of age on team behavior in small-sided games is examined in chapter 2. Two age groups, i.e., under-17 and under-19, played a series of 5-a-side games. Team behavior was determined with team distances (i.e., inter-team distances, stretch indices, and the length-per-width ratio), interaction patterns and game-to-game variability. The under-19 teams demonstrated more dispersion in their positioning on the pitch than the under-17 teams. In particular, older players showed larger distances in the lateral directions of the pitch. Interaction patterns and game-to-game variability were similar for the two age groups. The older players are, the wider they position on the pitch and the more they seem to exploit the width of the pitch. Findings of this chapter reveal that teams of different age groups use the available space on the pitch differently,

despite a comparable rhythmical pattern for the two teams.

In chapter 3, the concept of a relative pitch area – displaying the individual playing area per player – is introduced in order to investigate the effects of pitch size across various age groups (i.e., under-13, under-15, under-17, and under-19). More specific, a standard relative pitch area (i.e., 120 m^2) and a relative pitch area derived from the official match (i.e., 320 m^2) were applied in 5-a-side games, representing a small and a large pitch respectively. Thereafter, physical performance (i.e., distance covered, high intensity distance and number of sprints) and team tactical behavior (i.e., inter-team and intra-team distances, and tactical variability) were determined in both formats. A larger pitch size resulted in greater physical performance, increases in inter-team and intra-team distances, and greater tactical variability. Moreover, older age groups showed a greater increase in physical performance and inter-team distances, while younger teams showed a greater increase in intra-team distance on a large pitch. A match-derived relative pitch area affords teams more space to explore which results in a greater player distribution, varying distances between players, and a more physically demanding game.

Based on the findings of chapter 3, the match-derived relative pitch area has been applied on several small-sided games played in chapter 4. The small-sided games varied in number of players with 5, 7 and 9 players per team (goalkeepers included) and the individual playing area is similar to the match (i.e., 320 m^2). Subsequently, the relation between these small-sided games and the match was determined across various age groups, i.e., under-13, under-15, under-17, and under-19. Team tactical behavior was measured by calculating intra-team distances for all outfield players in the team, but also for 2-player and 4-player sub-groups. Sub-group analyses were a new approach introduced in this chapter in order to allow a better comparison of tactical behavior in the match and small-sided games. In addition, tactical variability is determined for all outfield players. The results show that intra-team distances increased with more players in a team and tactical variability decreased accordingly. Moreover, sub-group analyses revealed that intra-team distances were in general similar in the match as in these small-sided games. This indicates that the pitch in these small-sided games afforded sufficient space to the players in order to maintain a preferable distance to their team member. Furthermore, age-related differences were expressed by larger team distances during 5-a-side games than the match in younger age groups and smaller team distances in 7-a-side and 9-a-side games than the match in under-19. Overall, team structure and dispersion within teams can be maintained regardless of the number of players in the team as well as in the match as in the small-sided games.

A similar playing area as the match results in similar distances between players and this facilitates the tactical representation of small-sided games for the official match.

Behavior and performance in 11 vs. 11 during an official match and a training context were investigated in chapter 5. A match differs from a 11-a-side training game in match pressure, which originates from a consequence of winning or losing. This is typically present in the match, but it is absent in the training context in order to enhance learning. Team tactical behavior (i.e., inter-team and intra-team distances, and interaction patterns) and physical and technical performance were determined during official matches and 11-a-side training games in under-17 and under-19 teams. In general, inter-team and intra-team distances were similar in the match and in training, but teams moved more often coordinated over the pitch during the match. Consequently, players showed greater physical performance and less (accurate) passing in the match compared to 11-a-side games. The consequences of match pressure affected mainly individual performance and interaction patterns, and there was little influence on team distances. The match contributes to a greater coupling strength between teams and therefore stresses the physical and technical demands. An 11-a-side training game lacks the pressure of the match for an optimal representation.

Chapter 6 summarizes and discusses the main findings of this thesis. Pitch size, number of players, age, and match pressure accounted for differences in individual performance and team behavior in small-sided games. A match-derived relative pitch area ensured that small-sided games better represent the official match. It afforded a similar space for players to explore and to coordinate and compete with other players, likewise the match. Such a pitch area adds characteristics of the match to the small-sided game, which can be beneficial for the soccer learning process. Small-sided games played on a match-derived relative pitch area contribute to an extension of the current training program in daily soccer practice. A training program including small-sided games with a variation in pitch size and number of players affords players varying training stimuli, which will enhance the learning process of soccer.

Samenvatting

Dit proefschrift beschrijft het onderzoek naar kleine partijspelen in het jeugdvoetbal. Deze trainingsvorm wordt in de dagelijkse voetbaltraining gebruikt om voetbalvaardigheden te ontwikkelen, om spelers voor te bereiden op de wedstrijd en om het voetballeerproces te verbeteren. Variatie in de veldafmetingen en het aantal spelers per team in kleine partijspelen beïnvloeden de individuele prestaties en het teamgedrag. Een vergelijkbare ruimte als de wedstrijd kan bijdragen aan een optimale representatie van kleine partijspelen voor de wedstrijd.

In een wedstrijd liggen de veldafmeting, het aantal spelers per team en spelregels vast, maar deze kunnen in een klein partijspel eindeloos worden aangepast en gecombineerd. Met name aanpassingen in de veldafmeting en het aantal spelers beïnvloeden het gedrag van spelers en bovendien reageren verschillende leeftijdsgroepen anders op deze aanpassingen. Hiervoor is in hoofdstuk 1 een theoretisch en praktisch overzicht gegeven van individuele prestaties en teamgedrag in de officiële wedstrijd en kleine partijspelen in het jeugdvoetbal. Zowel in de wetenschap als de praktijk wordt er beweerd dat kleine partijspelen representatief zijn voor de officiële wedstrijd. Echter is het door de definitie en toepassing van een klein partijspel maar de vraag in hoeverre deze kleine partijspelen de wedstrijd kunnen nabootsen. In dit proefschrift zijn daarom een aantal kleine partijspelen gespeeld waarin de veldafmeting (op twee type relatieve veldafmetingen), het aantal spelers (met 5, 7, 9 of 11 spelers) en de leeftijd (van onder-13 t/m onder-19) zijn aangepast om prestatie en gedrag te onderzoeken én de relatie met de officiële wedstrijd te onderzoeken. De verwachting is dat een vergelijkbare speelruimte zoals in de wedstrijd de kleine partijspelen representatiever maken, ongeacht het aantal spelers. Daarnaast kunnen wedstrijdspanning en leeftijd de relatie tussen kleine partijspelen en de wedstrijd beïnvloeden en moeten daarom zorgvuldig worden onderzocht.

De invloed van leeftijd op het teamgedrag in kleine partijspelen is onderzocht in hoofdstuk 2. Twee leeftijdsgroepen (onder-17 en onder-19) speelden een aantal 5-tegen-5 partijen. Teamgedrag werd bepaald aan de hand van teamafstanden (inter-team afstanden, spreidingsindexen en een lengte-breedte ratio), interactiepatronen en de variabiliteit van de partijen. Onder-19 teams hadden een grotere spreiding op het veld dan onder-17 teams. Ze positioneerden zich met name breder op het veld, waardoor ze meer gebruik maakten van de breedte van het veld. De interactiepatronen en variabiliteit van de partijen waren gelijk voor deze twee leeftijdsgroepen. De resultaten uit dit hoofdstuk laten zien dat teams van verschillende leeftijden op een verschillende manier gebruikmaken van de beschikbare ruimte, ondanks de

vergelijkbare interactiepatronen van de twee teams.

In hoofdstuk 3 werd het concept van de relatieve veldafmeting geïntroduceerd. Deze veldafmeting geeft de individuele speelruimte aan. Het effect van twee type relatieve veldafmetingen werd onderzocht in verschillende leeftijdsgroepen, namelijk onder-13, onder-15, onder-17 en onder-19. In dit hoofdstuk werd een standaard relatieve veldafmeting van 120 m^2 en een relatieve veldafmeting die vergelijkbaar is met de wedstrijd (320 m^2) toegepast in 5-tegen-5 partijen. Dit komt overeen met respectievelijk een klein en een groot veld. De fysieke prestatie (afgelegde afstand, afstand op hoge snelheid en aantal sprints) en het teamtactische gedrag (inter-team en intra-team afstanden en tactische variabiliteit) werden vervolgens gemeten in beide partijvormen. De fysieke prestatie was groter, inter-team en intra-team afstanden namen toe en er was een grotere tactische variabiliteit op het grote dan op het kleine veld. Bovendien namen de fysieke prestatie en inter-team afstanden meer toe bij oudere leeftijdsgroepen op een groot veld, terwijl intra-team afstanden meer toenamen bij de jongere leeftijdsgroepen. Dit hoofdstuk laat zien dat een relatieve veldgrootte die is afgeleid van de wedstrijd meer ruimte biedt aan teams om te ontdekken. Daarmee worden de afstanden tussen spelers groter, komt er meer variatie in deze afstanden en worden de spelers fysiek meer uitgedaagd in de partijspelen.

Gebaseerd op de resultaten uit hoofdstuk 3, is de relatieve veldgrootte die is afgeleid van de wedstrijd toegepast op kleine partijspelen in hoofdstuk 4. Deze kleine partijspelen werden gespeeld met 5, 7 en 9 spelers per team (inclusief keepers), waarbij de individuele speelruimte vergelijkbaar was met de wedstrijd (320 m^2). De relatie van deze kleine partijspelen met de wedstrijd werd vervolgens onderzocht in verschillende leeftijdsgroepen (onder-13, onder-15, onder-17 en onder-19). Hiervoor werd het teamtactische gedrag gemeten, waarbij de intra-team afstanden zijn bepaald voor alle veldspelers in het team, maar ook voor subgroepen van 2 en 4 spelers. Deze analyses van subgroepen zijn een nieuwe aanpak om het tactische gedrag beter te kunnen vergelijken in de wedstrijd en kleine partijspelen. Daarnaast werd de tactische variabiliteit bepaald voor alle veldspelers. De belangrijkste resultaten waren dat de intra-teamafstanden toenamen en tegelijkertijd de tactische variabiliteit afnam wanneer er meer spelers in het team speelden. Bovendien waren intra-team afstanden binnen subgroepen over het algemeen gelijk in de wedstrijd en de kleine partijspelen. Dit geeft aan dat het speelveld voldoende ruimte biedt aan spelers om een prettige afstand tot hun teamgenoten te behouden. Er werden ook enkele verschillen tussen leeftijden gevonden. De teamafstanden waren tijdens 5-tegen-5 groter dan de wedstrijd bij jongere leeftijdsgroepen en de teamafstanden waren tijdens 7-tegen-7 en 9-tegen-9

kleiner dan de wedstrijd in onder-19. Over het algemeen waren de afstanden en ruimtes tussen spelers in de kleine partijspelen hetzelfde als de wedstrijd. Een vergelijkbare speelruimte als de wedstrijd zorgt voor een betere tactische representatie van kleine partijspelen voor de wedstrijd.

Verschillen tussen een wedstrijd en een training werden in hoofdstuk 5 onderzocht tijdens de officiële wedstrijd en een 11-tegen-11 trainingspartij. Een wedstrijd is anders dan een training, omdat er wedstrijdspanning ontstaat door een consequentie van winnen of verliezen. Dit ontbreekt vaak in een training om een veilige leeromgeving te bieden. Het teamtactische gedrag (inter-team en intra-teamafstanden en interactiepatronen) en de fysieke en technische prestatie werden gemeten tijdens officiële wedstrijden en 11-tegen-11 trainingspartijen van onder-17 en onder-19 teams. Over het algemeen waren de teamafstanden gelijk in de wedstrijd en de training, maar teams bewogen vaker gecoördineerd over het veld in de wedstrijd. Als gevolg daarvan renden spelers meer en hadden ze een minder (accurate) passing in de wedstrijd ten opzichte van de training. De wedstrijd zorgt voor een sterkere koppeling tussen teams en vraagt daardoor meer van de spelers op fysiek en technisch gebied. In een 11-tegen-11 trainingspartij ontbreekt de wedstrijdspanning die kan zorgen voor een optimale representatie.

In hoofdstuk 6 volgt een samenvatting en discussie van de belangrijkste resultaten uit dit proefschrift. De veldafmeting, het aantal spelers, de leeftijd en de wedstrijdspanning hadden invloed op de individuele prestaties en het teamgedrag in kleine partijspelen. Een relatieve veldafmeting die is afgeleid van de wedstrijd zorgde voor een verbeterde representatie van kleine partijspelen voor de wedstrijd. Het veld biedt dan een vergelijkbare ruimte aan spelers om ruimtes te ontdekken, samen te spelen en te strijden met andere spelers, zoals dat in de wedstrijd ook gebeurt. Zo'n veldafmeting voegt wedstrijdkenmerken toe aan kleine partijspelen en dit komt het voetballeerproces ten goede. Deze kleine partijspelen zijn een uitbreiding op het bestaande trainingsprogramma in de dagelijkse voetbaltraining. Een trainingsprogramma dat kleine partijspellen bevat met variatie in veldafmeting en aantal spelers biedt spelers een gevarieerd aanbod aan trainingsprikkels dat het leerproces van voetbal verbetert.

Curriculum vitae

Sigrid Olthof is geboren op 6 december 1988 in Almelo. Van 2007 tot 2012 studeerde ze Bewegingswetenschappen aan de Rijksuniversiteit Groningen. Tijdens haar afstudeerproject liep ze stage bij de jeugdopleiding van FC Groningen en deed ze onderzoek naar kleine partijspelen bij talentvolle voetballers. Dat resulteerde in de scriptie 'The older, the wider: on-field tactical behavior of elite-standard youth soccer players in small-sided games'.

In 2013 begon Sigrid als 'promovendus voetbal' aan het onderzoek naar kleine partijspelen bij talentvolle voetballers. Dit promotieonderzoek heeft ze uitgevoerd bij het Centrum voor Bewegingswetenschappen in samenwerking met de KNVB, FC Groningen, PSV en Vitesse. Positiedata en videobeelden werden gebruikt om de fysieke, technische en teamtactische prestatie te onderzoeken in wedstrijden en kleine partijspelen. Sigrid heeft in haar project geprobeerd om de voetbalwetenschap te vertalen naar het voetbalveld. Uiteindelijk resulteerde haar onderzoek in een proefschrift met vier gepubliceerde artikelen over kleine partijspelen en in een trainingsveld van FC Groningen waarop de lijnen zoals die volgden uit haar onderzoek waren uitgezet.

Tijdens haar promotie heeft Sigrid studenten begeleid bij individuele (afstudeer) projecten en gaf ze colleges voor het vak physiology of training and exercise. Daarnaast was ze lid van een expertisegroep van de KNVB rondom het rapport Winnaars van morgen, gaf ze workshops aan voetbaltrainers en -experts en heeft ze haar onderzoek gepresenteerd op verschillende (inter)nationale congressen. Voor haar presentatie op het World Congress on Science and Soccer in Rennes (Frankrijk) heeft ze in 2017 de Young Investigator Award gewonnen. In 2018 is ze genomineerd voor Researcher of the year voor uitstekend onderzoek door het Centrum voor Bewegingswetenschappen.

Sinds september 2018 is Sigrid werkzaam als junior docent bij het Centrum voor Bewegingswetenschappen. Ze geeft onderwijs in de mastervakken physiology of training and exercise, specialisatie sport, sport & talent, minor sport performance analysis en begeleidt studenten tijdens onderzoeksprojecten.

Vanaf juli 2019 begint Sigrid als postdoc bij het Exercise & Sport Science Initiative van de University of Michigan (VS). Op het domein van sport data and analysis gaat ze onderzoek doen en sportteams van de universiteit ondersteunen op het gebied van sportwetenschap.

List of publications

International journal

Olthof, S.B.H., Frencken, W.G.P., & Lemmink, K.A.P.M. (2019). A match-derived relative pitch area facilitates the tactical representativeness of small-sided games for the official soccer match. *Journal of Strength and Conditioning Research,* 33(2), 523–530.

Olthof, S.B.H., Frencken, W.G.P., & Lemmink, K.A.P.M. (2019). When something is at stake: differences in soccer performance in 11 vs. 11 during official matches and training games. *Journal of Strength and Conditioning Research,* 33(1), 167–173.

Olthof, S.B.H., Frencken, W.G.P., & Lemmink, K.A.P.M. (2018). Match-derived relative pitch area changes the physical and team tactical performance of elite soccer players in small-sided soccer games. *Journal of Sports Sciences,* 36(14), 1557-1563.

Olthof, S.B.H., Frencken, W.G.P., & Lemmink, K.A.P.M. (2015). The older, the wider: On- field tactical behavior of elite-standard youth soccer players in small- sided games. *Human Movement Science*, 41, 92–102.

Meeting abstract

Olthof, S.B.H., Frencken, W.G.P., & Lemmink, K.A.P.M. (2016). Small-Sided Games: An Optimal Training Tool to Represent Tactical Match Demands in Elite-Standard Youth Soccer Players? In D. Memmert (eds), *Full Issue PDF, Volume 87, Supplement 1, Research Quarterly for Exercise and Sport* (p S48)

Conference contributions

Olthof, S.B.H., Frencken, W.G.P. & Lemmink, K.A.P.M. (2018). Physical performance in small-sided games and official matches. 3rd *Science and Engineering Conference on Sports Innovations (SECSI)*, Groningen, the Netherlands

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Olthof, S.B.H., Frencken, W.G.P. & Lemmink, K.A.P.M. (2017). Age-related team-tactical differences in full-sized matches [poster]. *5th World Conference on Science and Soccer (WCSS)*. Rennes, France

Olthof, S.B.H., Frencken, W.G.P. & Lemmink, K.A.P.M. (2016). Small-sided games: an optimal training tool to represent tactical match demands in elite-standard youth soccer players? *6th International Teaching Games for Understanding Conference (TGfU)*. Cologne, Germany

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Olthof, S.B.H., Frencken, W.G.P. & Lemmink, K.A.P.M. (2015). Attacking and defending team behaviour in 8v8 and 11v11. *8th World Conference on Science & Football (WCSF)*. Copenhagen, Denmark

Frencken, W.G.P., Wijnbergen, M., Olthof S.B.H. & Lemmink, K.A.P.M. (2015). Team dynamics during transition moments in small-sided soccer games. *8th World Conference on Science & Football (WCSF)*, Copenhagen, Denmark

Olthof, S.B.H., Frencken, W.G.P. & Lemmink, K.A.P.M. (2014). Standardized small-sided games evoke different physiological responses in elite-standard youth soccer players. *19th Conference of the European College of Sport Science (ECSS)*, Amsterdam, the Netherlands

Olthof, S.B.H., Huijgen, B.C.H., Elferink-Gemser, M.T., Lemmink, K.A.P.M. & Visscher, C. (2013). Heart rate recovery during the Interval Shuttle Run Test in talented soccer players [poster]. *11th Groningen Sports Medicine Symposium*. Groningen, the Netherlands

Frencken, W.G.P., Olthof, S.B.H. & Lemmink, K.A.P.M. (2012). Pass-options in elite soccer [poster]. *3rd World Conference on Science and Soccer (WCSS)*. Ghent, Belgium

Dutch journal

Wierike te, S., Olthof, S., Huijgen, B., Norel van, J., Elferink-Gemser, M. & Visscher, C. (2013). Zelfregulatie en eigen verantwoordelijkheid. *De Voetbaltrainer*, 30 (194), 38-41

Achievements

Winner Hackaton City Logistics Groningen (2018) – Let's Gro, Groningen

Researcher of the Year nomination (2018) – Center for Human Movement Sciences, University Medical Center Groningen, University of Groningen

Young Investigator Award winner (2017) – World Congress on Science and Soccer, Rennes, France

Media

Internet (2013 – 2019)
OOG TV, Science and Medicine in Football, Voetbal International

Magazine (2018 – 2019)
De Voetbaltrainer

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Lijnen van een voetbalonderzoek worden makkelijker uitgezet met behulp van fijne teamgenoten. Binnen en buiten die lijnen kreeg ik van veel mensen – bewust of onbewust – de tijd en ruimte om samen te werken en te ontdekken. Dit dankwoord lijkt me een uitstekende plek om jullie daarvoor persoonlijk te bedanken.

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Wil de laatste Tukker het licht uit doen?

Cheers!

Sigrid